FUZZY MODELING APPROACH FOR DESIGNING URBAN LAND GRADING SYSTEM USING REMOTE SENSING AND GEOGRAPHICINFORMATION SYSTEMS:

THE CASE OF WELDIYA TOWN, NORTHEN ETHIOPIA

BY

ABRAHA TESFAY ABRAHA

A Thesis Submitted to the School of Earth Sciences in Partial Fulfillment of the Requirements for the Degree of Master of Science in Remote Sensing and Geographic Information Systems (GIS)

Addis Ababa University

Addis Ababa, Ethiopia

June, 2014

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This is to certified that the thesis prepared by ABRAHA TESFAY ABRAHA, entitled: ***Fuzzy Modeling Approach for Designing Urban Land Grading System by Using Remote Sensing and Geographic Information Systems, the Case of Weldiya, Northen Ethiopia*** and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Remote Sensing and GIS complies with the regulations of the university and meets the accepted standards with respect to the originality and quality.

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ABSTRACT

Land grade has a crucial role to develop appropriate standard benchmark prices on the lease of land and for the valuation of land related property. It also brings transparent and clear taxation systems that could establish sound and efficient land marketing system that would facilitate investment. However, the existing land grade system of the urban centers of Ethiopia such as Woldiya town has not been very successful in allowing the town to benefit from the advantages of having an efficient land grading system. The major reasons behind the limitations emanate from two main factors. The first reason is related to that important factors have not been exhaustively considered in designing urban land grading system. The second problem is related to a methodological approach on how land grade is prepared and implemented. Moreover, despite the fact that many geographical phenomena like land grade have fuzzy characteristics, currently most of the geographic phenomena are represented by crisp. Hence, the intent of this study is to develop conceptual fuzzy land grade model that is helpful to bring flexible land grading that enables to give decision makers an informed decision. In any of these methods, factor identification, weighting and integrating GIS and fuzzy logic approaches are important prerequisites that serve as platform to develop land grading. To design the conceptual model, five main factors have been considered, namely infrastructure, land use, topographic characteristics, visual and environmental factors and population density. Twenty four criteria were also considered under each main factor. In this study different data sources are utilized namely, Quick Bird image (2009) master plan of 1995 and 2009. The study confirmed that among the identified factors infrastructure takes the major share with 51% weighting influence and land use is in second position with weight influence 25.6 %. Topography, environmental and visual quality and population density factors have weight influences of 12.6%, 6.9% and 3.9 % respectively. This study used FAHP to determine criteria weights. The fuzzy consistency ratio (FCR) result was obtained to be 0.06. Based on the research findings, the most valuable land is situated in the old section of the town (CBD) where comprehensive infrastructure has been developed. The fuzzy analysis indicates that there is a gradual change in urban land grading pattern. This indicates that flexibility is another characteristic of fuzzy logic application. The final out put map indicates grade one, grade two and grade three have positively increased by 5.37%, 4.28% and 2.85%, respectively as compared to the existing land grading. This situation is happened due to infrastructure development and expansion of the town. To sum up, this paper indicates that the fuzzy modeling approach can avoid the loss of information that often arises when the strict Boolean logic is used on the basis of the crisp sets (Yes/No) and can produced a better and more reasonable result than crisp. It is also concluded that FAHP is the best alternative to determine the criteria weights from judgments of decision-making domain of experts.

Keywords: Fuzzy, crisp, land grade, master plan, urban planning.

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ACRONMS

ACCSA	Addis Ababa Chamber of commerce sectoral association
AHP	Analytical hierarchy process
CAD	Computer aid design
CBD	Central business district
DEM	Digital elevation model
DIP	Digital image processing
ECS	Ethiopian Civil service University
ERDAS	Earth Resources Data Analysis
EWE	Expert weight evaluation
FAHP	Fuzzy analytical hierarchy process
FAO	Food and Agriculture Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
FMCDM	Fuzzy multi-criteria decision making
GCP	Ground control point
GIS	Geographic Information System
GPS	Global Positioning System
km^2	Square kilometer
LULC	Land use land cover
m^2	Square meter
MCDA	Multi Criteria Decision Analysis
MWUD	Ministry of works and urban development
NUPI	National urban planning institution
RS	Remote sensing
UN	United Nations
UTM	Universal Transverse Mercator
US	United state of America

CHAPTER ONE

1 INTRODUCTION

1.1 Background

Urbanization is one of the most significant socio-economic issues of the twenty - first century and major challenge to policy makers, city managers and planners (UN Habitat, 2011). According to (http://www.unhabitat.org/documents/sowc10/r7.pdf) as the global urban population and number of towns and cities continues to increase, the need to understand and monitor the function of urban land use planning from physical, economical and environmental perspectives becomes an important issue.

Land has enormous socio-economic significance as a key productive asset and source of income (Eric and Joost, 2002).Studies by ACCSA (2009) suggest that land and real estate assets account for 45 to 75 percent of wealth in developing countries. This has become even more essential in urban land where the need to accommodate rapid urban growth and growing investment trends is more pressing. In Ethiopia, as elsewhere in the world, this enormous socio-economic significance stems from the fact that land is a source of wealth, economic growth and a source of basic survival of the majority of the population. In respect of urban land, this is further accentuated by the rapid urban development that leads to fast and radical changes in the physical, economic, social and administrative structures of the cities and towns.

It is understood, therefore, that this situation requires reforms in the policy, regulatory and institutional frameworks pertaining to land management system in the cities and towns. It will certainly require designing and implementing proper land provision procedures and valuation systems. That is why local governments in countries pursue urban land policy objectives and they rely on a vast range of policy tools to achieve appropriate land use decisions with regard to the issue of valuation and pricing that necessitate an appropriate land grading system. Based on the works of Daniel (1992) urban land grading is essentially the process to determine the relative value of urban land for taxation and investment purposes.

Grading urban land correctly and determining the land price are important and basic work to carry out the valuation exploitation and develop the real estate market. Furthermore, designing land grade must be built on objective evaluation and scientific evaluation and calculation of land quality (Liu, 2002).Therefore, Land grade has a crucial role to play in that it grades urban land into different level of valuation scales making it possible for efficient urban land valuation and pricing.

In Ethiopia, even there are not many studies to inform us about the urban land grading and valuation mechanism different experience has shown that the most commonly used conventional or traditional approach by the Ethiopian government is area based grading. This method matches with the expert weight evaluation (EWE) method which manually overlays land use maps. This manual method is not only labor intensive, but also may distort the real values of certain land parcels because of its inability to represent fuzzy characteristics of land grading. There is today more than before that planners are being confronted by multi dimensional urban problems in the new urbanism that call for new techniques to automate the process and model the fuzzy nature of urban land values.

In this study to solve this problem a model containing fuzzy multi-criteria decision making technique is designed. The fuzzy approach allows decision makers to give interval judgments which can capture a human‘s appraisal of ambiguity when complex multi-attribute decision making problems are considered (Ibrahim *et al.*, 2011). It is, therefore, the motivation of this research to use a methodology that integrates GIS, fuzzy logic and the AHP to design a model for urban land grading. It is also important to mention that so far different studies have indicated explicitly how to incorporate fuzzy set theory into GIS modeling processes to handle the fuzzy characteristics of geographic phenomena, but few studies have indicated explicitly how to incorporate fuzzy set theory into GIS modeling processes in an urban context especially in urban planning discipline. Therefore, this study can potentially enhance the understanding of how to incorporate fuzzy set theory into fuzzy land grade modeling processes there by help urban planners and policy makers to improve the valuation mechanism of urban land.

1.2 Problem Statement

Land management in urban Ethiopia is in transition and faces many interrelated challenges. The overarching challenge is the process of attempting to replace the old system of urban land valuation by more market- oriented of long term leases (NUPI, 2005). According to MWUD (2006), Ethiopia is not only least urbanized but also most urban centers in the country are predominantly unplanned. One manifestation of this situation is the absence of legal framework and clear methodology for preparation, implementation and revision of urban land grading plan. In urban Ethiopia ground realities reveals that the existing land grading for various urban localities like Woldiya town is not effective due to the fact that the existing land grading and valuation system is static and subjective exercise than a dynamic process tied to real market development.

Currently, the insufficient flexibility of land grade system in Ethiopia hinders its usefulness for achieving objectives of the urban development policy, such as fostering real estate markets and supporting land investment. As a result, the existing land grade has not been very successful in allowing the town to benefit from the advantages of having an efficient land grading system. Distorted land market and irrelevant basis for setting benchmark lease prices can be taken as a manifestation of this insufficient land grade system.

No one can deny that the institutional weakness and limited performance capacities in the regulatory framework can be one reason behind the insufficient land grade system of the town. However, the major reasons behind the limitation emanates from two main factors. The first reason is due to the fact that, some major factors that are of paramount importance in determining the grade of land had been left out. Studies suggest that the development of urban land grading system is influenced by numerous factors. These include land use socio-economic, environmental quality and infrastructure (Daniel, 1992, Liu, 2002 and MUDW, 2006). However, in the existing practice those factors have not been exhaustively considered in designing urban land grading system. Furthermore, it did not take into account the implication of negative externalities which in reality do significantly affect the value of the land. For example, topographic difference by slope has not been considered. Therefore, identifying the influential factors for urban land grade development is another aspect of this study.

The second problem is related to a methodological approach how land grade is prepared and implemented. Evidence from the existing land grade map of the town has shown that the land grading system is developed in the context of traditional urban land uses models. It had been developed based on the classification of the town into four concentric zoning categories i.e. The CBD, intermediate zone, sub-urban and urban-rural fringes. This type of traditional and homogenization does not leave much room for capturing the land value because it lacks flexibility and ignores the reality on ground. This traditional approach depends on manually overlapping of land use maps. This manual method is not only labor intensive, but also may distort the real values of certain land parcels because of its inability to represent fuzzy nature of urban land grading.

It is logical that under conditions of rapid urbanization competition for secure and serviced land increases. This places pressure on existing valuation systems and requires professionals to design different land use management tools which encourage efficient land valuations. The central issue, hence, becomes what methods and approaches of land use management are best to achieve these objectives. Hence, developing predictable and flexible land grade model to land valuation has remained an important issue. To fulfill this premises, in this study it was based on integration of fuzzy logic approach and geospatial tools with set of criteria derived from the spatial aspects, environment, policies and national and local experience to develop conceptual fuzzy land grade model in Weldia town. This system could benefit urban planners and decision makers to obtain a prototype of land grading system in the urban centre and the output will contribute to urban land valuation and lease bench mark pricing.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of this study is to develop conceptual model for fuzzy urban land grading system for Woldiya town.

1.3.2 Specific Objectives

- To identify factors that influence fuzzy urban land grading system.
- To develop fuzzy urban land grading map for the study area by using fuzzy logic approach.
- To evaluate the suitability of fuzzy approach for designing urban land grading.

1.4 Research Questions

To realize the above stated objectives the following research questions have been formulated.

- What are the main influencing factors for fuzzy urban land grading?
- How to develop a fuzzy urban land grading conceptual model?
- What are the similarities and differences between the existing land grading and the new fuzzy land grade? What are the reasons?

1.5 Significance of the Study

The developed method is not only facilitate the organization and management of factor data layers but it also enable users to take full advantage of location information contained in databases that can support the application of spatial statistical information. The results can be also used as a policy-support document for governmental authorities who have direct or indirect connections to land development and management. It is also expected that with small modifications the method can be used for other cities and towns as well. Furthermore, the research output can be used as a road map for those who want to develop and customized GIS based land grade plan. This study can also be used to fill knowledge gap and it will render academic advantages that will be used as reference or guideline while designing urban land grade system. Finally, the outcome of this research can be used as a precursor for further scientific research.

1.6 Limitation of the Study

It is often the case for a study to have some sort of limitation/s during its course of undertaking. One manifestation of limitation of this research is the challenge to obtain recent imageries and finest resolution which are important for identification of urban features. In the in availability to secure recent imageries it is difficult to identify all the newly developed buildings, roads and new constructions of urban features. In order to overcome this problem, the researcher repeatedly undertook field observations to verify actual urban land use characteristics and used other related hard copy based data (land use map and base map) which has its own implication on time and resources.

The second limitation is related to the number and types of factors aggregated to design urban land grade conceptual model. Due to the complexity of urban land grading, more numbers of multifaceted factors must have been included than what have been incorporated in this study. This is because the researcher was not able to get data to add more equally important factors. Therefore, the manner in which the researcher analyzed urban land grading within the study area is based on spatial factors that leave room for further research to consider all these limitations and incorporate other physical and socio-economic and spatial factors like (household income, building height, parking, detail geological and urban characteristics).

1.7 Structure of the Thesis

The thesis report is structured in the following way:

Chapter one states the general context of the study including the general introduction and back ground, problem statement of the study, research objectives, research questions, significant of the study, limitation of the study and operational definition of terms.

Chapter two gives comprehensive review of literature on the theory of land grading and land values. The literature includes identification and explanation of the main factors that influence urban land grading and land values and common land value attributes.

Chapter three presents the description of the study area, settlement trend of the town and population characteristics of the study area. In addition, it explains the research methodology that deals about what method is adopted, how spatial and non spatial data are collected, analyzed and organized in to meaning full information that can be used in the conceptual model. The concept of fuzzy set theory and its application in GIS environment is also explained. Based on the analysis under taken methodology flow chart is developed to show the overall methodology.

Chapter four presents the results obtained from all process involved in the developed fuzzy urban land grading system.

Chapter five discusses the research results in relation to the stated objective and other research findings.

Chapter six provides the conclusion and recommendation of the research. Conclusions are draw from the research results and findings. Recommendations, including suggestions for further research are finally forwarded.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 An Overview of Urban Spatial Structure and Land Use Models

2.1.1 Introduction

The manner in which a city grows has significant influence on land use patterns (Bernard, 2003). In several literatures a city is considered as a complex system. It consists of numerous interactive systems and is affected by diverse factors including land use policies, infrastructure development and land market behavior. As urban areas have grown over time, they have become increasingly complex, and the speed of urban development causes remarkable changes in land use.

The fast change in urban spatial structure in cities is characterized by a high level of complexity and dynamic change in land value behavior (Eric and Joost, 2002). The study of urban land use is generally based on three different descriptive models. These models were developed taking in to account the patterns of urban land use in early industrial cities of the U.S. The following section has the purpose to summaries the models which have an influence on how land is used and value is changed in urban development. The urban land use models that will be looked in to include the concentric zone model, sector model and multiple nuclei model of urban land uses.

2.1.2 Concentric Zone Theory

There is fairly large literatures on urban land use models. Following the work of Fabiyi (2006) on these urban land uses, theories have reviewed that the concentric ring model, also known as the Burgess model was the first to explain distribution of social groups within urban areas. The concentric rings in this model depict urban land use in concentric rings. The Central Business District (CBD) is in the middle of the model and the city expands in rings with different land uses (Fig 2.1). These rings were originally defined as (1) central business district, (2) zone of transition, (3) zone of independent workers' homes, (4) zone of better residences and (5) zone of commuters.

However, Burgess assumes a generalized geographic space and strict action space that explain it in the form of mono centric city. Furthermore, the important influential factors in land use change like topography and transportation system are not considered. Yet, the notion of mono centric city (especial when we consider first and second level cities) does not reasonably represent real land use patterns in Ethiopia.

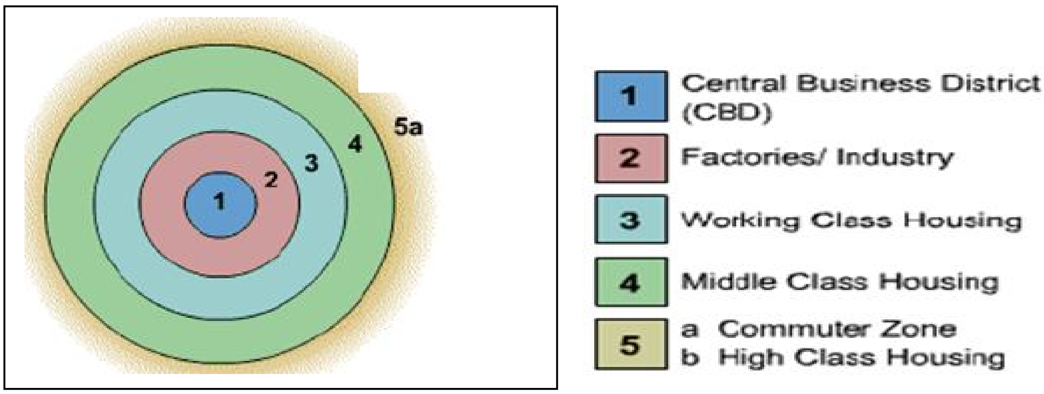

Figure 2.1 Concentric Zone Model

Source: http://geoearth.uncc.edu.html

2.1.3 Sector Model

The sector model also known as the Hoyt model was proposed in 1939 by economist Homer Hoyt. It is a model of urban land use that modifies the concentric zone model of city development. Hoyt theorizes that cities tend to grow in wedge-shaped patterns or sectors emanating from the central business district and centered on major transportation routes. Higher levels of access means higher land values, thus, many commercial functions would remain in the CBD but manufacturing functions would develop in a wedge surrounding transportation routes. Hoyt's model attempts to broadly state a principle of urban organization. The sector model (Fig 2.2) also recognizes that the CBD is not the only focal point of urban activity (Fabiyi, 2006).

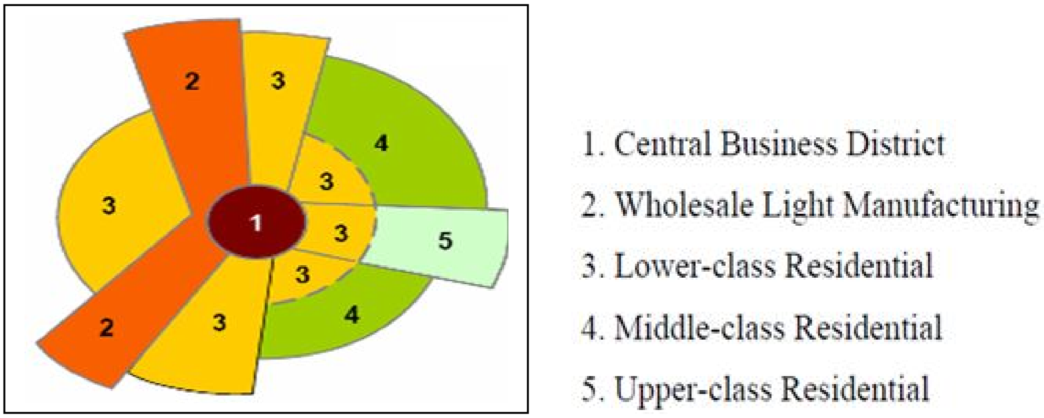

Figure 2.2 Sector Model

Source: http://geoearth.uncc.edu.html

2.1.4 Multiple Nuclei Theory

Multiple nuclei theory is concerned with urban spatial organization that views urban areas as areas composed of multiple centers or nuclei including commercial centers, industrial centers and offices. By 1945, it was clear to Harris and Ullman that many cities did not fit the traditional concentric zone or sector model. Multiple nuclei theory advanced by Harris and Ullman is based on the fact that many towns have many nuclei that serve as centers of agglomerative growth rather than a simple CBD around which all urban activities revolve. This theory surpassed previous attempts at explaining the spatial distribution of urban activity by acknowledging important influences such as topography and accessibility. Even though, the number of nuclei and their functions varies from city to city, generally, the larger the city, the more nuclei it will contain (Fabiyi, 2006).In Ethiopia Addis Ababa and vibrant secondary cities shares this type of land use model.

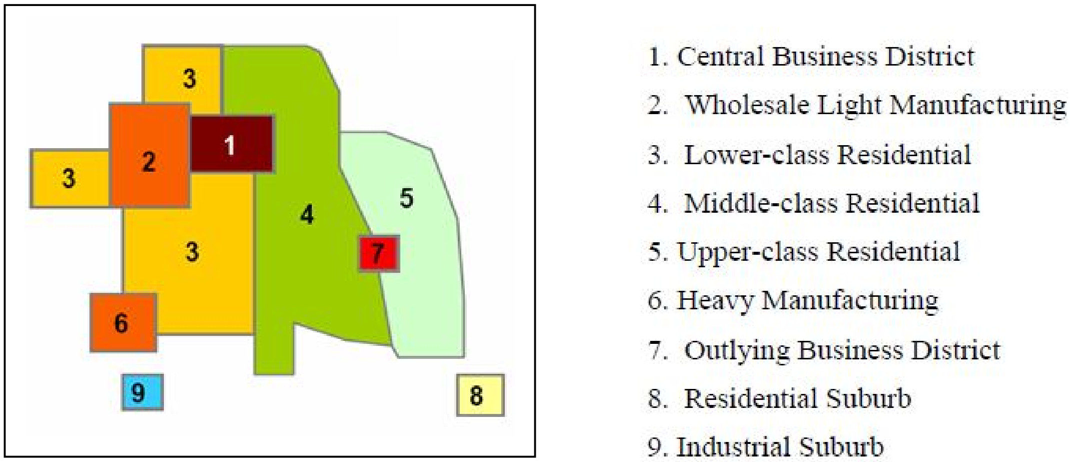

Figure 2.3 Multiple Nuclei Model

Source: http://geoearth.uncc.edu.html

2.2 An Overview of Urban Land Value and Models

2.2.1 Introduction

Land value is essential in all sorts of decision relating to real estate buying, selling, financing, managing and leasing (Recep *et al.,* 2006). According to Bernard (2003, as cited in Alonso, 1964 and Muth, 1969) much of the theory of urban land use is based on the work of and draws on concepts from microeconomics. Within this theory patterns of land use are determined by land values that are in turn related to land grading.

2.2.2 The Von Thunen Model and Land Value Behavior

The land value analysis of land use goes back to the pioneering work of von Thünen. Early in the 19th century von Thünen developed a model of land use that showed how market processes could determine land uses and how they were spatially distributed over a theoretical geographic area (Fig 2.4). The model compares the relationships between production costs, market price and the transport cost of an agricultural commodity and is expressed as follows.

R= Y (p− c) – Y*F*m

R= Land rent

Y= Yield per unit of land

c= Production expenses per unit of commodity

p= Market price per unit of commodity

F= Freight rate

m= Distance to market.

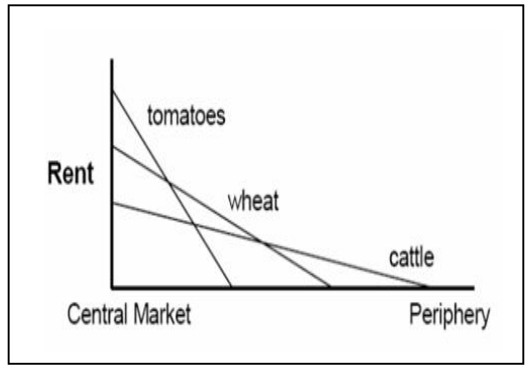

Figure 2.4 Von Thunen Model

Source: Ping (2005)

Traditionally the urban structure approach of land price dominated the main philosophy of land value behavior (Bernand, 2003).The early and well-known theories of Von Thünen have laid the foundation of land price and land use theories. The Von Thünen model is an excellent illustration of the balance between land cost and transportation costs (Eric and Joost, 2002).

2.2.3 Bid-Rent Theory

The central market town in the Von Thünen model is interpreted by Alonso as a city with a central business district (CBD) in the city centre. Bid rent theory is a geographical theory that refers to how the price and demand on land changes as the distance towards the CBD (central business district) increases. This is based upon the idea that retail establishments wish to maximize their profitability, so they are much more willing to pay more for land close to the CBD and less for land further away from this area. This feature of urban land use theory causes land values to decline with distance from the center city (http://www.uncc.edu./hscample/land value/b-model/c-bidrent.html).

To this day, most major cities have a traditional core that is identifiable by its concentration or agglomeration economies. The most valuable land is situated in the old section of the city where comprehensive infrastructure has been developed during the long history of growth (Daniel, 1992). As it is indicated in figure 2.5, as distance from CBD increases the value of land decreases.

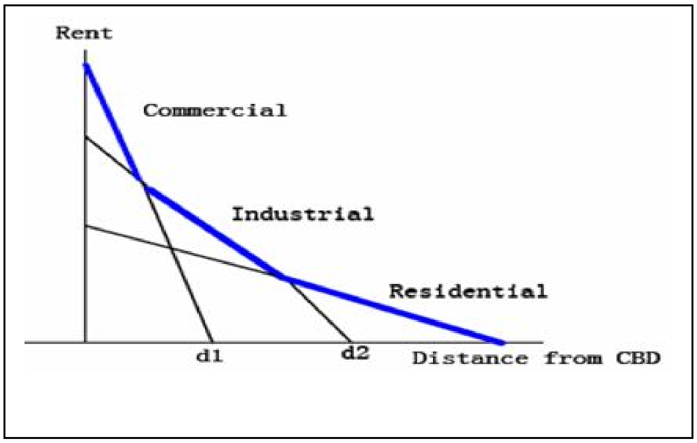

Figure 2.5 Model of urban land market by Alonso (1964)

Source: Ping (2005)

2.2.4 Contemporary Approach of Urban Land Value

Recently, more scientific analysis has been employed to try to establish the relevant factors that determine land value other than distance to city center. For example, land values around nodes and intersection poles can increase land value. Furthermore, the real world city is not purely mono-centric; they have other major activity areas beside the CBD. Long commercial colliders are sprinkled. As it is indicated in ping (2005), studies in developing countries confirm that residential land value is not only related to distance but also to different factors.

2.3 Review of Influential Factors for Designing Land Grading

2.3.1 Theoretical Underpinning of the Factors

The development of urban land grading system is influenced by multi criteria factors. These include land use, environmental quality and infrastructure (Daniel, 1992, Liu, 2002 and MUDW, 2006). Although the major factors affecting land grading could be similar in different cities and towns, the level at which they influence land grading is different in different cities and towns. Few land grading studies done by researchers have concentrated only on the proximity analysis (how far or how close to a given center of facilities). In doing so, they failed to consider other potential influencing factors such as topographic factors that could have influence in determining urban land grading. Mean while, determination and classification of the factors are also difficult because the characteristics of these factors can be objective and subjective and changes according to people desire (Recep *et al.,* 2006).

According to Liu (2002), grading urban land correctly and determining the land price is an important basic work to carry out compensational exploitation and develop the real estate market. According to him, the land grading must be based on objective and scientific evaluation and calculation of land quality. Parallel with this, Daniel (1992) also notes that urban land valuation is a very complex process, which usually requires simultaneous considerations of many socioeconomic, location and physical factors and it is essentially the process to determine the relative value of a certain block of urban land for taxation and investment purposes. Hence, based on the discussion above and ground reality, the concept of land grade of urban centers is related to land quality which has direct relation to valuation. Accordingly, the number of land grading factors cannot be limited, but, it can be limited depending on the aim and scale of the work. Based on this fact, it is possible to say that it is logical to apply different factors in different conditions and contexts of local urban planning.

2.3.2 Explanation of the Influential Factors for Designing Land Grading

2.3.2.1 Land Use Factors

Most factors that are incorporated in designing urban land grading have their roots in the family of land use types. Moreover, Land valuation is originated from the need for a comprehensive assessment of land performance when used for different specified purpose (FAO, 2007). According to Jun (2004), the commercial land value is greater than manufacturing land value and manufacturing land value is greater than residential land value. This indicates that compared with other land use types, the commercial land use values are the most centralized with higher values in the downtown area and decreasing quickly with the increase in distance. Thus, the land use value in Ethiopia is consistence with Jun’s exploration.

Land value mainly depends on its location (Nisanci, 2006). Therefore, in reality, each land use category does not have the same effect on land grading. Hence, it can be said that each type of urban land use will have its own influence and the combination of those land use functions will define land grade. To illustrate these phenomena, it is useful to discuss some of the land use categories. The following section presents the detail review of each land use (residential land value, commercial land value and industrial land values).

Influencing Factors for Residential Land Value

Land has special characteristics compared to other economic goods. The supply of land is fixed every parcel of land has a fixed location which is a unique property and the use of a parcel of land affects the use and value of surrounding parcels (Eric and Joost, 2002). An important matter about the housing lands is that they can be living areas and an investment tool; it is not only evaluated by the structural characteristics of the property but also it is evaluated physically and physiologically by the other urban and spatial particularities surrounding the land (Mehmet and Ayse, 2009). According to Recep (2006), factors that influence residential value includes location, proximity and accessibility.

Influencing Factors for Commercial Land Value

Based on the reality on the ground, and evidences from different literatures, the location of a commercial area in the urban center has profound impact on the valuation system. The factors are commonly related to the functional attributes of the commercial centre (main center, sub center) and commercial colliders in the given neighborhood. Hence the influence of the commercial land use takes the highest share in urban land grading.

Generally, in Ethiopian context, the values and the lease price of those sites in the central business district (CBD), namely sites along major highways that are well provisioned in terms of basic infrastructure and utility services were set on the higher side compared to those with peripheral locations that lie along less important roads and in areas deficient in basic infrastructure (ACCSA, 2009).

Influencing Factors for Manufacturing Land Value

With respect to the physical conditions and the potential to meet economic development, manufacturing function is treated as one of the key lands uses (MUDW, 2006). The existence of handicraft industry (non-motorized) as well as small scale industries (small electric or motor and warehouses of small size (agricultural products and industrial products) and if they are near to centers or sub-centers and accessible to major collector roads, they have the capacity to generate commercial activities and to develop the neighborhood to mixed use area. Accordingly, as neighborhoods change to mixed use, the land grade also changes.

2.3.2.2 Topographical Factors

Many physical and biological processes happening on the landscape are highly correlated with topographic position (http://www.jennessent.com/pdf). Topography/surface slope is one of the most important elements for impacting urban and rural development and construction which not only affects the spatial structure within the city layout, but also to the economic investment and engineering measures (Luo *et al.*, 2008).

2.3.2.3 Accessibility Factors

The accessibility factors can be defined as the distance between every single street and public service units stand at the nearest location of these streets (Genevieve *et al.*, 2010). The public service units are characterized as primary schools, high schools, universities, cultural zones, health services, commercial centers(CBDs, shopping centers, retails), entertainment areas, recreational areas(green fields, sport areas, children's playgrounds), police stations and place of worship (Mehmet and Ayse, 2009).

2.3.2.4 Road and Urban Transport Factors

The higher value of land at the CBD reflects the capitalization of transport cost savings into the price of land. This feature of urban land use theory causes land values to decline with distance from the city center **(**http://www.uncc.edu./hscample/land value/b-model/c-bidrent.html). Road accessibility is one of the most important factors for urban development as it provides linkage between the settlements (Mohammed *et al.,* 2006).

2.3.2.5 Visual and Environmental Quality Factors

Sensitive areas should be identified and means for their conservation should be outlined in the local urban planning. Areas such as, steep slopes, unstable lands, ground water replenishing areas, areas for wild life protection and forest land for the preservation of genetic diversity should be protected (Planning manual, 2008). To safeguard human settlement areas, no building sites should be allowed within the ground water basin (Mehmet and Ayse, 2009). Housing areas should be located at least 200 meters away from industry areas. In addition, the location must be far at least 5 km from any waste water treatment station (Mohammed *et al.,* 2006).

2.3.2.6 Future Development Opportunity Factors

Local development plan must identify strategic investment areas and devise means for their development (local development manual, 2008). Factors considered under this category are development factors that relate to the power of a given location to attract investment. Whether the development plan of the city has reserved or allocated the area for a specific type of development that the user wants it for use. Evidence drawn from (Greg and Frances, 2004) suggests that assessing the impact of planning on development potential and hence land value is necessary to examine both the development plan and other relevant planning documents.

2.3.2.7 Population and Housing Density Factors

Demographic pressure and competition for land have not only modified the rural/urban equilibrium; they have also changed existing land use patterns (Fabiyi, 2006). Based on the reality on the ground, distribution of population density within the given area varies from place to place. It is known that most municipal service delivery is related to the population number. In principle, the more we have the people in an area the more the service is required. Based on the service provided, the neighborhood quality will be changed; as a result the land grade will be improved.

2.4 Reviews on Methods of Selecting Criteria

2.4.1 Introduction

According to (Saba *et al.,* 2011), there is yet no universal agreed upon mechanism of defining evaluation criteria for multi criteria decision making. Logically, to be able to accurately define all aspects of the decision problem, there is generally a need for a large number of criteria to be included in the process. Choosing a small number of criteria might result in over simplification. On the other hand, each evaluation criterion must be comprehensive and measurable and the set of criteria should be close to being complete so that it covers nearly all aspects of the problem. The selected criteria should also be relevant to the analysis and it should decomposable (broken into parts to simplify the process), non-redundant (avoid double counting) and minimal. Also, the selection process has to be tailored to the needs of the problem at hand and be based on the characteristics of the system that is analyzed.

Unfortunately, so far, there has not been adequate literature on urban land grading; the criterion has been derived from limited resources. These criteria are obtained from literature review of different master plan reports (national and local urban planning manual and lease reports) and discussion with land experts and members of the town land valuation group. The remaining criteria are benefiting type; this means that the higher the value, the more preferable the alternative for the best location i.e from the concept of location suitability criteria (suitability analysis). In determining or measuring the value given to each criterion and in establishing the level of desirability of each attribute, different measurements and ranges have been used where they are applicable to existing national norms and standards. However, in the absence of known standards expert judgment had been used.

2.4.2 Criteria Setting for Land Grading

2.4.2.1 Criteria for Topographical Factor

The important factor associated with topography includes aspect, elevation and slope (Mohammed *et al.*, 2006). Topography/ surface slope is one of the most important elements for impacting urban and rural development and construction which not only affects the spatial structure within the city layout, but also to the economic investment and engineering measures (Luo *et al.*, 2008). Table 2.1 shows criterion to topography factor.

Table 2.1 Criterion to topography factors

Factor	Sub factor	Unit of measurement	Range	Classification	Implication
Topography	Slope	Degree	0-5	Most suitable	Grade one
			5-10	Very suitable	Grade two
			10-15	suitable	Grade three
			15-20	Less suitable	Grade four
			>20	Least suitable	Grade five
	Aspect	Degree	North	Most suitable	Grade one
			east	Very suitable	Grade two
			South	suitable	Grade three
			West	Less suitable	Grade four
			Flat	Least suitable	Grade five

Source: NUPI (2005)

2.4.2.2 Criteria for Land Use Factor

In the case of Addis Ababa, land rent for residential activities ranges from a maximum of 2.38 birr /m^2 to a minimum of 0.09 birr/m^2, and rental rates and lease price for commercial area ranges from a maximum of 4 birr /m^2 to a minimum of 0.8 birr/m^2. Land uses rental rates and lease price for industrial ranges from a maximum of 2 birr /m^2 to a minimum of 0.4 birr/m^2.This shows that commercial areas are most valuable while industrial areas are very valuable as compared to residential areas (ACCSA, 2009). Table 2.2 shows criterion to land use factor.

Table 2.2 Criterion to land use factor

Factor	Sub factor	land use	Classification	Implication
Land use	Land use categories	Commerce	Most suitable	Grade one
		Mixed use	Very suitable	Grade two
		Manufacturing	suitable	Grade three
		Residential	Less suitable	Grade four
		Others	Least suitable	Grade five

Source: MUDW (2006)

2.4.2.3 Criteria for Accessibility Factor

Evidence from literature shows that residential property values are a function of access to services as well as to jobs (Genevieve *et al.*, 2009). Table 2.3 and Table 2.4 describe criteria for accessibility factor for different health and educational institutions.

Table 2.3 Level, requirement area and catchment area of educational services

Level of education	Space requirement	Catchment in radius	Range	Classification	Implication
Kindergarten	500-3000 m^2	< 1km	0-250	Most suitable	Grade one
			250-500	Very suitable	Grade two
			500-750	suitable	Grade three
			750-1000	Less suitable	Grade four
			>1000	Least suitable	Grade five
Primary education	1.5 – 2.5 ha	< 4km	0-1000	Most suitable	Grade two
			1000-2000	Very suitable	Grade three
			2000-3000	suitable	Grade four
			3000-4000	Less suitable	Grade five
			>4000	Least suitable	Grade two
Secondary education	2.5-6 ha	< 5 km	0-1250	Most suitable	Grade one
			1250-2500	Very suitable	Grade two
			2500-3750	suitable	Grade three
			3750-5000	Less suitable	Grade four
			>5000	Least suitable	Grade five
Post-secondary education schools	2.5-6 ha	< 6 km	0-1500	Most suitable	Grade one
			1500-3000	Very suitable	Grade two
			3000-4500	suitable	Grade three
			4500-6000	Less suitable	Grade four
			>6000	Least suitable	Grade five

Source: MUDW (2008)

Table 2.4 Level, requirement area and catchment area of health services

Level Service	Space Requirement	Catchment in radius	Range	Classification	Implication
Health post	0.11ha	< 1km	0-250	Most suitable	Grade one
			250-500	Very suitable	Grade two
			500-750	suitable	Grade three
			750-1000	Less suitable	Grade four
			>1000	Least suitable	Grade five
Health center	0.45 – 0.6 ha	< 2km	0-500	Most suitable	Grade one
			500-1000	Very suitable	Grade two
			1000-1500	suitable	Grade three
			1500-2000	Less suitable	Grade four
			>2000	Least suitable	Grade five
District hospital	2 ha	<6km	0-1500	Most suitable	Grade one
			1500-3000	Very suitable	Grade two
			3000-4500	suitable	Grade three
			4500-6000	Less suitable	Grade four
			>6000	Least suitable	Grade five

Source: MUDW (2006)

2.4.2.4 Criteria for Urban Transport Factors

Transportation systems provide mobility for people and goods and influence patterns of urban growth as well as the level of economic activities. This, in turn influences the value of land grade of the neighborhood. Table 2.5 shows criterion to urban transport factor.

Table 2.5 Criteria for urban transport factors

Factor	Sub factor	Type of land use	Classification	Implication
Transport services	Service location	Sites within 500 m from main highway	Most suitable	Grade one
		Sites between 500 - 1000 m from main highway	Very suitable	Grade two
		Sites between 1000 - 1500 m from main highway	suitable	Grade three
		Sites between 1500 - 2000 m from main highway	Less suitable	Grade four
		Sites more than 2000 m from main highway	Least suitable	Grade five

Source: Luo *et al.* (2008)

2.4.2.5 Criteria for Security Factors

Close proximity to a local administration, police and kebele security office implies reduction in transport expenses for households in travelling for justice. In addition, individuals may feel secured if there is police station nearby that they frequently can report for any unsecured feeling. Table 2.6 shows criterion to security factor.

Table 2.6 Criteria for security factors

Factor	Sub factor	Unit distance	Range in meter	Classification	Implication
Security	Security institutions	Meter	< 500	Most suitable	Grade one
			500- 750	Very suitable	Grade two
			750- 1000	suitable	Grade three
			1000-1250	Less suitable	Grade four
			>1250	Least suitable	Grade five

Source: Patil *et al.* (2012)

2.4.2.6 Criteria for Population Factors

The study of population distribution is very important for the purpose of service delivery. Different literatures advise to professionals to incorporate population density in land grading and suitability analysis (MUDW, 2006 and Patil *et al.,* 2012). Table 2.7 shows criterion to population factor.

Table 2.7 Criteria for population factors

Factor	Sub factor	Range	Classification	Implication
Population	Population density	<5000	Most suitable	Grade one
		5000- 10000	Very suitable	Grade two
		10000- 15000	suitable	Grade three
		15000-20000	Less suitable	Grade four
		>20000	Least suitable	Grade five

Source: Patil *et al.* (2012)

2.4.2.7 Criteria for Visual and Environmental Quality Factors

Criteria for visual and environmental quality factors should be identified and all projects should submit environmental impact assessment report (Planning manual, 2006). Environmental factors which may include visual and environmental quality, ecological character and disposal site management have profound impact on land quality. Table 2.8 shows criterion to environmental factors.

Table 2.8 Criterion to visual and environmental quality factors

Factor	Sub factor	Unit	Range in meter	Classification	Implication
Environment	Flood line or stream line distance	Meter	>500	Most suitable	Grade one
			400 -500	Very suitable	Grade two
			300 – 400	suitable	Grade three
			200 – 300	Less suitable	Grade four
			< 200	Least suitable	Grade five
	Distance from waste disposal site	Meter	> 5000	Most suitable	Grade one
			3000 – 4000	Very suitable	Grade two
			2000 – 3000	suitable	Grade three
			1000 – 2000	Less suitable	Grade four
			<2000	Least suitable	Grade five

Source: Khalil (2008)

2.5 Type of Integration Models

Various models were used for real world events simulation in GIS environment. There are various integration models that categorized by kind of functions and their executive practice. They are often divided in to two broad categories called data driven model and knowledge driven or conceptual model. Data driven models are executed based on existent solutions and value computation. In knowledge driven method or conceptual model factors are identified using expert experience. Next, different criteria are identified and their dimensions are uniformed. Then, their weights are calculated and normalized in the defined range using an appropriate scale (Jian and Philippa, 2009). According to them, this method is more applicable for multifactor decision making and analysis. Hence this study adopted the conceptual model for designing the urban land grading of the study area.

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Description of the Study area

3.1.1 Location

Woldiya is located in North Wollo Administration Zone which is one of the ten zones in the Amhara National Regional State (ANRS). It is the capital town of North Wollo Zone, which is 360 km far from Addis Ababa. Woldiya is placed approximate between latitude 11° 47' 34" − 11° 50' 29" N and longitude 39° 33' 58" – 39° 37' 06" E (Fig3.1). In the current administrative setting the town has second level urban administrative status and serves as the seat of North Wollo Administrative Zone. The town has built up area of about 1881ha and administratively divided in to three kebeles (Woldiya master plan report, 2009).

3.1.2 Settlement Pattern of the Town

The town of Woldiya in earliest time has had a nearly a radial shape which was developed following the main roads leading to Addis Ababa, Mekelle and Woreta. (Woldiya master plan report, 2009). During the field work it is observed that there is significant number of settlements of town that fall under slum type of settlements. These settlements are composed of dilapidated houses and deteriorated infrastructures, i.e. they are old enough and found in the central place of the town. Relatively they are with better access to infrastructure and service.

There are on the other hand, new settlements under establishment that are not properly provided with the necessary infrastructure and services. The general built-up of the town is dominated by radial shape following the main existing roads and the suitable terrains for urban use. This shape has been formed due mainly to the search for road and other infrastructure services and the suitable terrains for residential settlement and related activities of urban use. This situation implies that the settlement characteristics are affected by the nature of topography and availability of infrastructure and services.

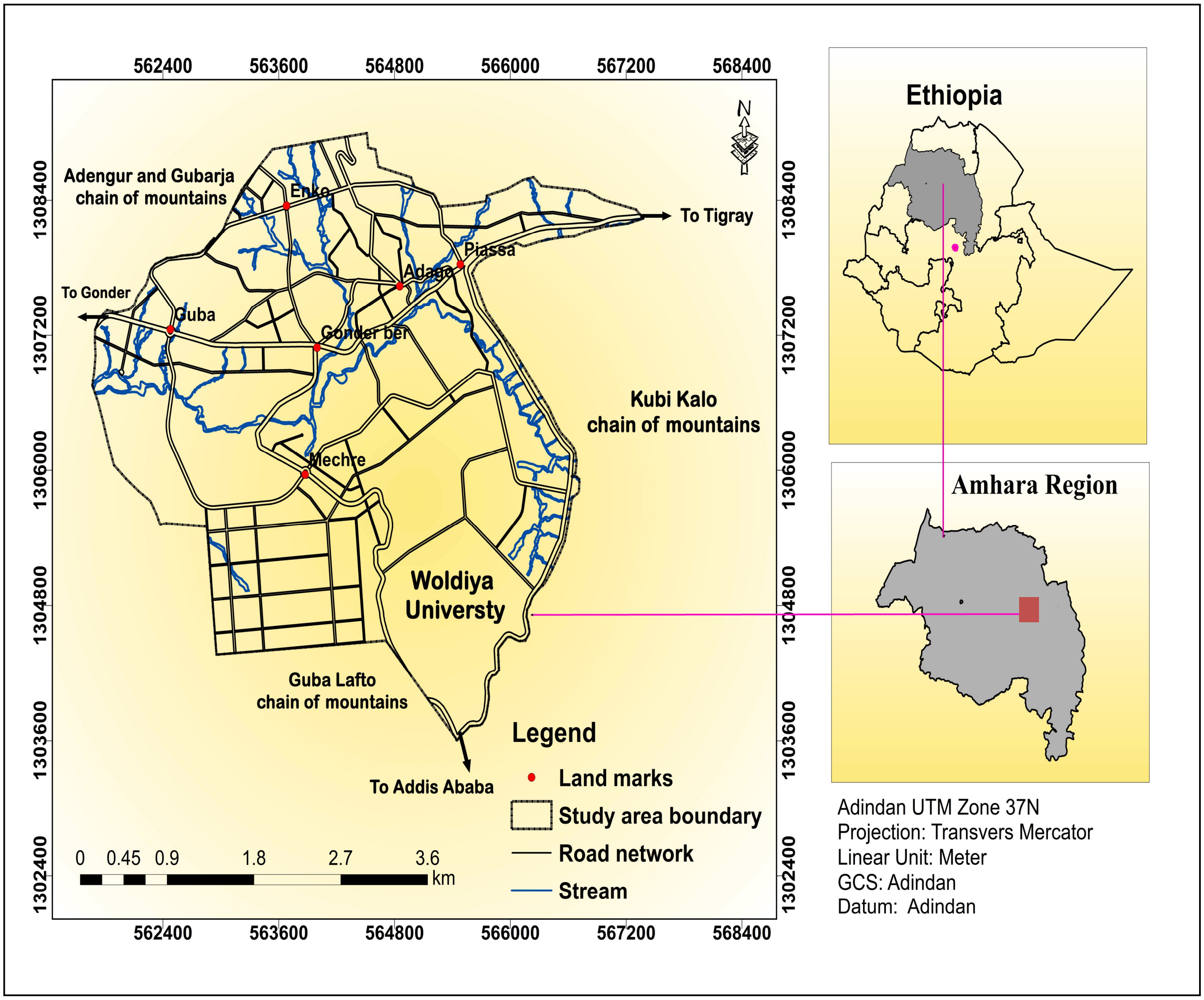

Figure 3.1 Location map of the study area

3.1.3 Physiographic Setting of the Study Area

The nature of the land of the town of Woldiya is rolling, hilly, and mountainous. The average altitude in the built-up part of the town is estimated to be 2000m above sea level. The existing built-up area of the town is situated on the rugged topography. The presence of high mountains such as Adengur and Gubarja in the east, and small mountains Kubi Kalo and Guba Lafto/ Tekle Haimanot in the west and south respectively have been obstacles of the expansion of the town particularly eastwards.

The natural drainage of the town pattern is dissected into major water sheds namely, Netif Dengay, Arerao, Adengur, Shellie streams. Many parts of the town coupled with the nature of topography are exposed to erosion, gully formation and flood problems.

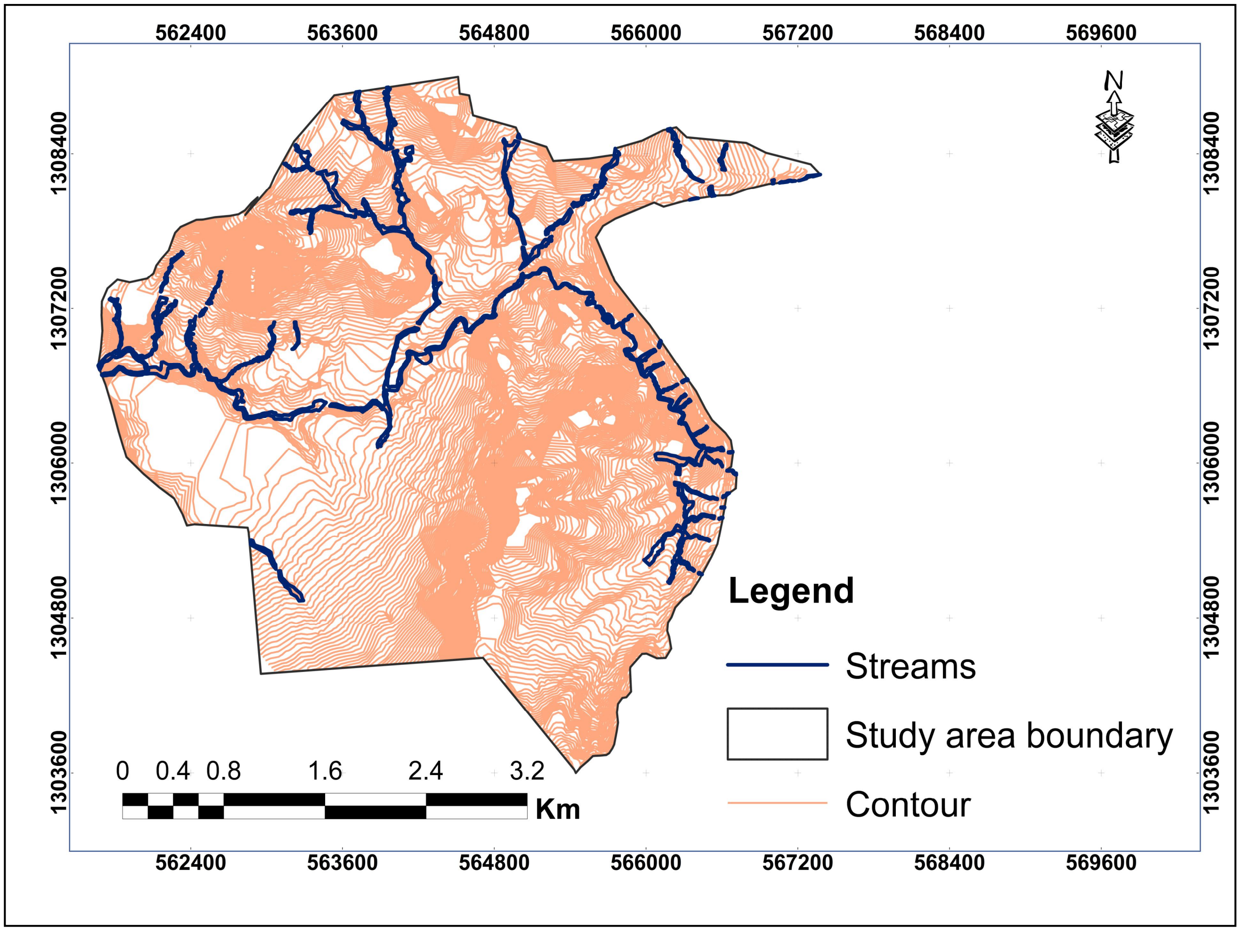

Figure 3.2.A Streams in Woldiya Town

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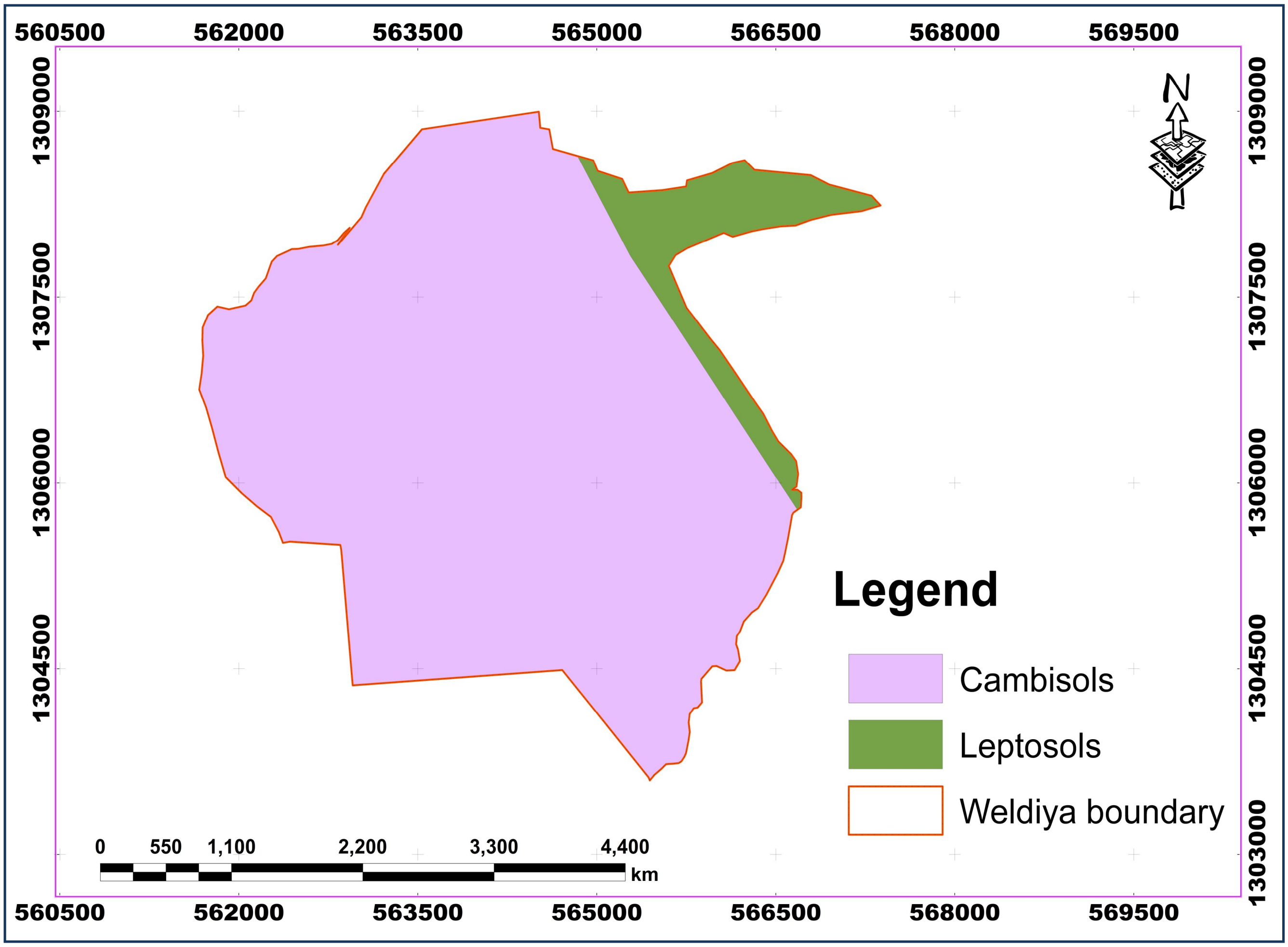


Figure 3.2.B Soil classification of Woldiya Town

Source: Central statistic of Ethiopia (CSA)

3.1.4 Demographic Characteristics of Woldiya Town

A survey conducted by CSA indicates that Woldiya had a population of 9,409 in 1970. In 1984 the town was reported to have a population of 15,325. Comparison of these two earlier population figures shows that the population of Woldiya town was growing at the rate of 3.5% between the years 1970-1984. After 10 years that is in 1994, it was reported that the population size of Woldiya was counted to be 24,533. Comparably, the third Ethiopian census of 2007 has revealed that there were about 46,126 people residing in the town during the count (CSA, 2007). The data further indicates that there were 22,990 (49.84%) male to 23,136 (50.16%) female. Based on the projection made during the master plan preparation, the population size in year 2013/2014 is about 64,802 and after five year i.e by 2019, the projected population size will be 82,613. This implies that the population is increasing at the rate of 4.86%. This increment has its own impact in the land use planning and the overall municipal service provision.

3.2 Data Sources and Methods

3.2.1 Data Sources and Data Collection Methods

The data used in this study were collected both from primary and secondary sources. Primary data were captured from satellite imagery and field observations. Furthermore, the opinion of selected experts from all over groups has been sought to ascertain the influence of different factors on the development of land grade. The secondary data were collected from the National Urban Planning of Ethiopia, the Regional Urban Planning of Amhara Regioanal state and Weldia town administration master plan report. The data used in this research were categorized into two parts called spatial data and non-spatial data (Table 3.1).

The spatial factors that have influence on land grade are mainly obtained from the digital maps obtained from the master plan of the town. The different CAD maps which includes road plan, land use plan, green and recreational areas, public facilities and amenities has been converted to spatial data layers and stored in the Geographic Information System data database. To represent the different vector formats the shape file format is used in Geographic Information System (GIS).

Table 3.1 Data sources of the study

Type of data	Data description	Data format	Sources
Spatial	Topo map scale 1:50000 1139 B_1	Digital	EMA
	2m contour interval	Digital	Prime plc
	Satellite Imagery(QuickBird)	Digital	Prime plc
	Town Land use plan (2009)	In CAD	Woldiya Town and Prime plc
	Town Land use plan (1995)	In CAD	Woldiya Town and Prime plc
	Town road plan(2009)	In CAD	Digitizing features
	Town boundary	In CAD	Digitizing features
	Land grade map (1995)	Hard copy	Woldiya Town
Non spatial	Norms and standards	Literature	MUDW
	Land grading factors	Literature	Literature review
	Lease proclamation	Document	MUDW
	Population statistic	Document	CSA
	Master plan report	Document	Woldiya Town and Prime plc

3.2.2 The Research Methods

3.2.2.1 Data Processing Methods

The study involves the collection of Topo map from Woldiya municipality and relevant authorities. The required satellite imagery for the study area was obtained from the prime consulting. Processing the imagery and image interpretation for development of land use and different vector maps was done in ERDAS Imagine software. The obtained maps were studied and analyzed to understand the characteristics of the urban land function.

According to Lillesand and Kiefer (2000), any spatial data under consideration should be geo-referenced i.e its position must be fixed with respect to latitude and longitude correctly before doing further activities.

Based on this context, in the study area 25 uniformly distributed ground points were collected by using differential GPS which has accuracy error of less than 0.03 (Table 3.2) and then all digital maps and satellite image were georeferenced and rectified to UTM zone 37N coordinate system. Finally, a first-order polynomial model was applied and all data were resembled using the nearest neighbor method. Geometric correction was resulted in RMSE between 0.030 and 0.60. In the next step, visual interpretation was done and residential, nonresidential and agricultural areas were identified. Identifying features was based on color, tone, shape, texture and size. Field actualizing was also used for better interpretation.

Table 3.2 GPS points used for Geo referencing

No	Easting	Northing
1	563090	1307002
2	563102	1307002
3	563900	1306878
4	563899	1306897
5	563900	1306878
6	562059	1307311
7	562069	1307311
8	562056	1307360
9	562068	1307360
10	562056	1307360
11	562080	1307340
12	562088	1307340
13	562080	1307340
14	563172	1307064
15	563172	1307079
16	563172	1307064
17	563348	1307213
18	563348	1307222
19	563348	1307213
20	563501	1307291
21	563504	1307279
22	563501	1307291
23	563452	1307755
24	563462	1307755
25	563452	1307755

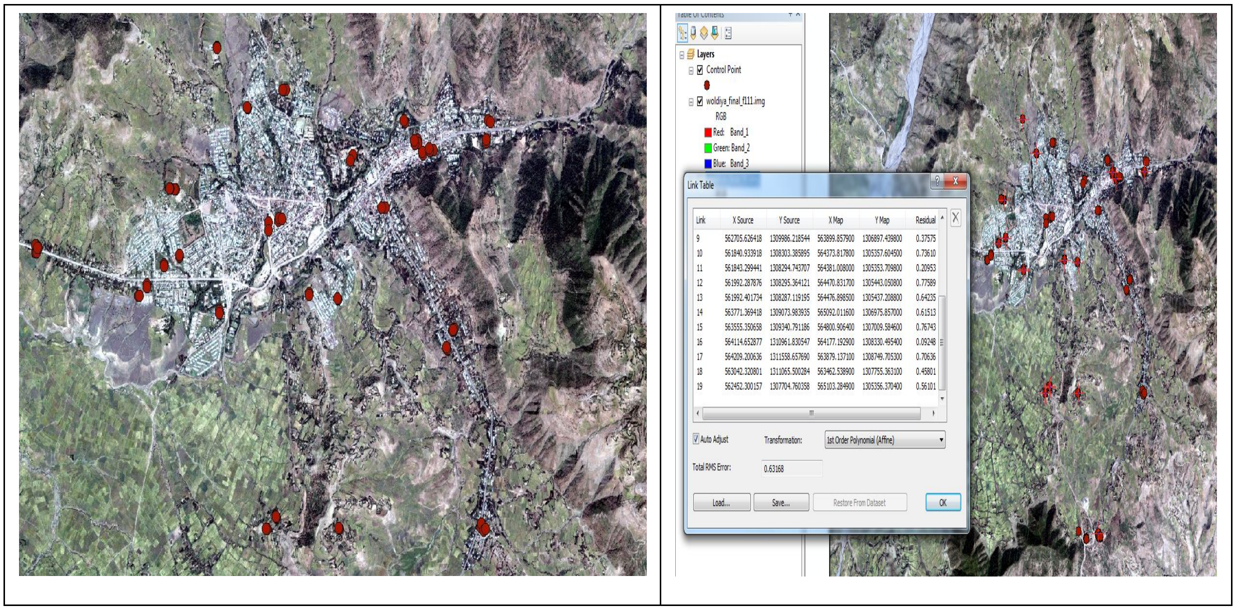


Figure 3.3 Process of georeferencing and corresponding RMSE

3.2.2.2 Method of Preparing Input Layers

At this stage usable map layers in GIS environment were prepared in order to be analyzed and used as input for the land grade development. To develop land grade of the study area, various thematic layers were created by using GIS software (Fig 3.4). The layers were derived from high resolution images (Quick Bird 0.60 m resolution) and CAD files. 3D analysis was used to create TIN model from digital topographic map (2 m contour interval) to generate elevation, slope and aspect factor maps. Each factor map was prepared in a manner that can support to the overall goal of the conceptual land grade model.

3.2.2.3 Method of Standardizing the Input Layers

Before aggregating the input layers in a model they must be on the same scale. This process is known as standardization and involves assigning the same dimensionless continuous scale, either 0–255 or 0–1, to all the input layers (Rodney *et al.*, 2011).This process indicates the unit of measurement of each factor map as belonging to a set ranging from 0.0 to 1.0 or 1 to 255, indicating a variation from non-belonging to complete-belonging or least valuable to most valuable. In this study 0–1 continuous scale is used.

3.2.2.4 Knowledge Based Judgment Method

The land grade that is determined by multiple criteria assessment method can request professional knowledge based feedback and recommendation due to some probable weakness of the methodology. Hence, this paper was used expert or knowledge based approach as one mechanism to strengthen the overall study process. This process is expected to be performed in the post land grade classification. Post land grade classification is considered to be necessary because multiple decision paths way can verify the correctness of classification in land grade designing process.

3.2.2.5 Method of Determining Valuation Scales

In spite of the fact that there is several number of grading scales in every country, however, the most common ways of scale and valuation urban land are five types. For example, urban land grading in China are five types which categorized under most valuable, very valuable, valuable, less valuable and least valuable (Daniel,1992). In Ethiopia, even there are not many studies to inform us about the urban land grading and valuation mechanism different experience has shown that the urban centers are classified into five valuation scales (grade one, grade two , grade three, grade four and grade five).This implies that each land rents decreased progressively from higher (grade one) to lower (grade five). In order to prepared land grading at a town-wide scale, bringing a certain level of homogeneity to land in Woldiya becomes essential. Depending on the availability of relevant data, and manageability of the task, a block had been used as the geographical unit of analysis.

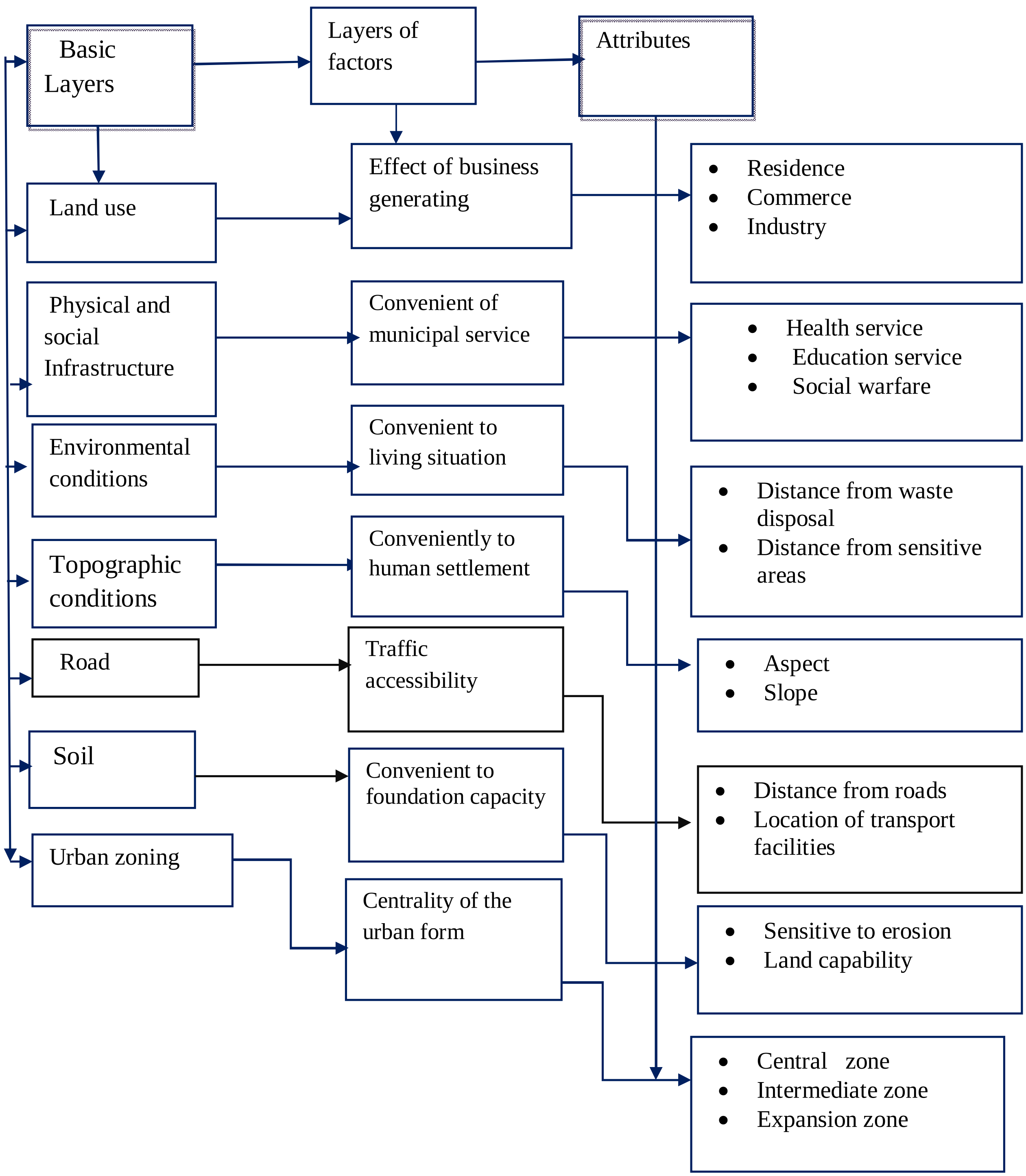


Figure 3.4 Method of layer organization of the study area

3.3 Fuzzy Sets and Fuzzy GIS Modeling Method

3.3.1 Introduction

Classical and conventional (traditional) land suitability methods are based on Boolean's two valued logic that defines different land suitability classes completely distinctive. These methods have many disadvantageous in description of capabilities and suitability for different applications. Therefore, fuzzy modeling based on fuzzy sets theory is the best method in land suitability assessment (Fang *et al.*, 2013).

In human thinking and language we often use uncertain or vague concepts; our thinking and language is not binary, i.e., black and white, zero or one, yes or no. In real life we add much more variation to our judgments and classifications. These vague or uncertain concepts are said to be fuzzy (Chang *et al.*, 2008). To discuss how to incorporate fuzzy set theory into the spatial modeling process first it is necessary to introduce some of the basic fuzzy theory concepts. Thus, this section provides an introduction to the use of fuzzy sets and fuzzy logic for the combination of GIS with fuzzy set theory and for developing conceptual model which is known as GIS Fuzzy Modeling (GISFM).

3.3.2 The concept of Crisp Sets and Fuzzy Sets

3.3.2.1 Crisp (Boolean) Sets

In general, in set theory an element is either a member of a set or not. We can express this fact with the characteristic function for the elements of a given universe to belong to a certain subset of this universe. We call such a set a crisp set (Tang, 2004).

Definition 3.1 (Crisp set) Let A be a subset of a universe X. The *characteristic function* χ_A of A is defined as $\chi_A : X \to \{0,1\}$ with

$$\chi_A(x) = \begin{cases} 1 & \text{iff} \quad x \in A \\ 0 & \text{iff} \quad x \notin A \end{cases}$$

From definition 3.1, the crisp membership is two-valued. It is binary, i.e., black and white, zero or one, yes or no. However, in real life we experienced much more variation to our judgments and classifications.

3.3.2.2 Fuzzy Sets

Definition3.2 **(Fuzzy set).** A *fuzzy set* A of a universe X is defined by a *membership function* μ_A such that $\mu_A : X \rightarrow [0,1]$ where $\mu_A(x)$ is the *membership value* of x in A. The universe X is always a crisp set.

If the universe is a finite set $X = \{x_1, x_2, \ldots, x_n\}$, then a fuzzy set A on X is expressed as $A = \mu_A(x_1)/x_1 + \mu_A(x_2)/x_2 + \cdots + \mu_A(x_n)/x_n = \sum_{i=1}^{n} \mu_A(x_i)/x_i$. The term $\mu_A(x_i)/x_i$ indicates the membership value to fuzzy set A for x_i. The symbol "/" is called *separator*, Σ and "+" function as *aggregation* and *connection* of terms.

If the universe is an infinite set $X = \{x_1, x_2, \ldots\}$, then a fuzzy set A on X is expressed as $A = \int_X \mu_A(x)/x$. The symbols $\int$ and "/" function as aggregation and separator.

The *empty fuzzy set* $\varnothing$ is defined as $\forall x \in X,\ \mu_\varnothing(x) = 0$.

For every element of the universe X we trivially have $\forall x \in X,\ \mu_X(x) = 1$, i.e., the universe is always crisp. (Daniel, 1992)

From definition 3.2, it can be understand that 0 (zero) is assigned to those locations that are definitely not a member of the specified set, 1 is assigned to those values that are definitely a member of the specified set and the entire range of possibilities between 0 and 1 are assigned to some level of possible membership (the larger the number the greater the possibility).

3.4 Integrating Fuzzy Logic and Analytical Hierarchy Process

3.4.1 Introduction

In the real word, human decision making are very vague and uncertain in a number of ways. The most criteria have interdependent and interactive features so they cannot be evaluated by conventional methods due to their subjectivity and vagueness (Daniel, 1992 and Fang, 2013). Thus, to approximate the human subjective evaluation process, it would be more suitable to apply a fuzzy method to incorporate the decision makers' attitude towards preference, overall performance value of each alternative can be obtained based on the concept of fuzzy multiple criteria decision making (FMCDM) (Rodney and Tesfalem, 2011 and Jayasree *et al*., 2013).

One of the useful methods of multifactor analysis is analytical hierarchy process (AHP) introduced by Saaty (1980). AHP has become one of the most widely used methods for the practical solution of multi factor analysis problems. But the main shortage of AHP is that it deals with people's expert judgment as a crisp number between 1 and 9. However, this doesn't handle the uncertainty associating to these judgments (Ibrahim *et al*., 2011).In similar way studies suggested that the conventional AHP technique of expressing decision maker's judgments in the form of single numbers does not fully reflect a style of human thinking in the real-world system (Rodney and Tesfalem, 2011).

According to (Fereydoon *et al.,* 2010 and Abedi *et al.,* 2013), integrating fuzzy logic into the AHP process will give much better and more exact representation between criteria and alternatives. It is therefore the intent of this research to use a methodology that integrates GIS, fuzzy logic and AHP to model urban land grade in Woldiya town. To realize this method fifteen experts from both academic institution and urban planning agencies which comprising five from the university of expert scholars (include land use urban, engineering and surveying, urban planning and urban management), five from the government departments (include land use planning department and construction department) five from private company (urban planning firms) were surveyed about the relative weights of the criteria considered in this research.

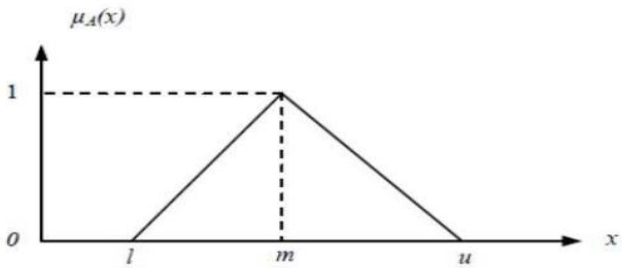
3.4.2 Modeling Fuzzy Analytical Hierarchy Process (FAHP)

3.4.2.1 The Concept of Triangular Fuzzy Numbers (TFNs)

According to the definition of Chang (1996) fuzzy numbers are a fuzzy subset of real numbers that represents the expansion of the idea of the confidence interval**.** When using TFNs, the decision maker's judgment is represented as an interval defined by three real numbers or parameters, expressed as (l, m,u), where l is the lowest possible value, m is the middle possible value and u is the upper possible value in the decision maker's interval judgment.

Each TFN is associated with a triangular membership function, which describes the TFN domain. Moreover, by using the concept of TFNs the fuzzy judgment matrices can be constructed to obtain pair wise comparisons for criteria at each level of the hierarchy (Ibrahim *et al.*, 2010).

Triangular membership functions can be represented mathematically and graphically by equation 3.1 and Figure 3.5.



$$\mu_f = \begin{cases} \frac{x-1}{m-1}, & l \le x \le m \\ \frac{u-x}{u-m}, & m \le x \le u \\ 0, & otherwise \end{cases}$$

Equation 3.1

Fig. 3.5 Fuzzy triangular number

3.4.2.2 Determining Weights of Criteria by Using Triangular Fuzzy Numbers

Commonly FAHP methods are developed based on triangular fuzzy numbers proposed by Chang (1996). Likewise, this research also used the fuzzy extent analysis proposed by Chang. According to Chang by using TFNs via pair wise comparison the fuzzy judgment matrix Ã (aij) can be expressed mathematically as equation 3.2.

$$\tilde{A} = (\tilde{a}_{ij})_{n\times n} = \begin{bmatrix} (1,1,1) & (l_{12},m_{12},u_{12}) & \cdots & (l_{1n},m_{1n},u_{1n}) \\ (l_{21},m_{21},u_{21}) & (1,1,1) & \cdots & (l_{2n},m_{2n},u_{2n}) \\ \vdots & \vdots & \vdots & \vdots \\ (l_{n1},m_{n1},u_{n1}) & (l_{n2},m_{n2},u_{n2}) & \cdots & (1,1,1) \end{bmatrix}$$

Equation 3.2

$$where \quad \tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) = \tilde{a}_{ij}^{-1} = (1/u_{ji}, 1/m_{ji}, 1/l_{ji}) \quad for \quad i, j = 1,\ldots,n \quad and \quad i \ne j.$$

The steps of Chang’s fuzzy extent analysis can be summarized as follows.

Step.1 Sum each row of the fuzzy comparison matrix Ã. Then normalize the row sums (obtaining their fuzzy synthetic extent) by the fuzzy arithmetic operation.

$$\widetilde{S}_i = \sum_{j=1}^{n} \widetilde{a}_{ij} \otimes \left[\sum_{k=1}^{n} \sum_{j=1}^{n} \widetilde{a}_{kj} \right]^{-1} \qquad \text{Equation 3.3}$$

Where $\otimes$ denotes the extended multiplication of two fuzzy numbers. To obtain $\sum_{j=1}^{n} \widetilde{a}_{ij}$, the fuzzy addition operation was applied to the fuzzy numbers in the fuzzy judgement matrices, such that,

$$\sum_{j=1}^{n} \widetilde{a}_{ij} = \left(\sum_{j=1}^{n} l_j, \sum_{j=1}^{n} m_j, \sum_{j=1}^{n} u_j \right)$$

To obtain $\left[\sum_{k=1}^{n} \sum_{j=1}^{n} \widetilde{a}_{kj} \right]^{-1}$, the fuzzy addition operation was applied to the column values in the matrix obtained from Equation 6, followed by computation of the inverse of the resulting vector such that,

$$\left[\sum_{k=1}^{n} \sum_{j=1}^{n} \widetilde{a}_{kj} \right]^{-1} = \left(\frac{1}{\sum_{k=1}^{n} u_k}, \frac{1}{\sum_{k=1}^{n} m_k}, \frac{1}{\sum_{k=1}^{n} l_k} \right)$$

Step. 2 Estimate the priority vector W = (w_1,.....,wn) of the fuzzy comparison matrix Ã as follows:

$$w_i = \frac{l_i + u_i + m_i}{3}, i = 1, \ldots\ldots n \qquad \text{Equation 3.4}$$

Step. 3 Finally, the calculated weights of each criterion were normalized.

$$Nw_i = \frac{w_i}{\sum_j^n = 1 w_j}, i = 1, \ldots\ldots n \qquad \text{Equation 3.5}$$

Table 3.3 Triangular fuzzy number of linguistic variables used in this study

Linguistic variables	Crisp numbers	Triangular fuzzy numbers	Reciprocal triangular fuzzy numbers
Extremely strong	9	(9,9,9)	(1/9,1/9,1/9)
Very strong	8	(6,7,8)	(1/8,1/7,1/6)
Strong	6	(4,5,6)	(1/6,1/5,1/4)
Moderately strong	5	(2,3,4)	(1/4,1/3,1/2)
Equally strong	1	(1,1,1)	(1,1,1)
Intermediate	3,4,5	(3,4,5)	(1/5,1/4,1/3

3.4.2.3 Proposed TFNs and Linguistic Variables

In this study, all identified factors are compared against each other in a pair wise comparison matrix which is a measure of relative importance among factors. Saaty (1980) suggested a scale for comparison consisting of values ranging from 1 to 9 which describe the intensity of importance by which a value of 1 expresses equal importance and a value of 9 is given to those factors having an extreme importance over another factor.

Whenever fuzzy characteristics are required the crisp pair-wise comparison matrix of each expert must be fuzzified. Furthermore, in order to perform a pair wise comparison among fuzzy parameters, linguistic variables must be defined for the levels of preference (Chang, 1996). Hence, the following expressions are used to compare two criteria by six basic linguistic terms, as extremely strong, very strongly important, strong, moderately strong important, intermediate and equally important. Each scale of fuzzy number is defined by three parameters of the symmetric triangular fuzzy number i.e left point, middle point, and right point. The crisp and fuzzified pair-wise comparison matrix is given in Table 3.3

3.4.3 Determining Weights of Criteria

3.4.3.1 The Fuzzy Judgment Matrix of the Study

After identification of all criteria and sub criteria the fuzzy judgment matrix of the study was accomplished by using pair wise comparison method. The fuzzy judgment matrix of the study is given in Table 3.4

Table 3.4 The fuzzy judgment matrix of the study

	C1	C2	C3	C4	C5
C1	(1,1,1)	(2,3,4)	(4,5,6)	(6, 7,8)	(9,9,9)
C2	(0.25,0.33,0.5)	(1,1,1)	(2,3,4)	(3,4,5)	(6,7,8)
C3	(0.167,0.2,0.25)	(0.25,0.33,0.5)	(1,1,1)	(1,2,3)	(4, 5,6)
C4	(0.125,0.143,0.167)	(0.2,0.25,0.33)	(0.33,0.5,1)	(1,1,1)	(1,2,3)
C5	(1/9,1/9,1/9)	(0.125,0.143,0.16)	(0.167,0.2,0.)	(0.33,0.5)	(1,1,1)

C1	C2	C3	C4	C5
Infrastructure	Land use	Topographic characteristics	Environmental and visual quality	Population density

3.4.3.2 Calculation of Score Weight for Each Criterion

Expert’s opinion available for the various criteria in the form of linguistic variable as presented in Table 3.4 is being converted into fuzzy numbers. To normalize differences existing in expert opinion simple average of fuzzy numbers for all the linguistic variables has been calculated and the corresponding weights are being worked out and presented in the Table 3.5. Fuzzy weights for all criteria are expressed in the form of following row matrix and the score weight of each criterion is calculated in the following equation.

$$Nw_i = \frac{w_i}{\sum_j^n = 1 w_j}, i = 1,......n \qquad \text{Equation 3.6}$$

Table 3.5 Normalized weights for each criterion

	C1			C2			C3			C4			C5			Weight
Cl	0.605	0.561	0.4931	0.5594	0.6352	0.667	0.5335	0.5155	0.4898	0.52957	0.4828	0.4444	0.4286	0.375	0.3333	**0.510181**
C2	0.151	0.185	0.2465	0.2797	0.2117	0.16675	0.2668	0.3093	0.32653	0.26478	0.2759	0.2778	0.2857	0.2917	0.2963	**0.25571**
C3	0.101	0.112	0.1233	0.0699	0.0699	0.08338	0.1334	0.1031	0.08163	0.08826	0.1379	0.1667	0.1905	0.2083	0.2222	**0.126106**
C4	0.076	0.08	0.0823	0.0559	0.0529	0.05503	0.044	0.0515	0.08163	0.08826	0.069	0.0556	0.0476	0.0833	0.1111	**0.068937**
C5	0.067	0.062	0.0547	0.035	0.0303	0.02785	0.0223	0.0206	0.02041	0.02913	0.0345	0.0556	0.0476	0.0417	0.037	**0.039066**
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

3.4.3.3 Calculating the Fuzzy Consistency Ratio (FCR)

To determine whether consistency is maintained in assigning the weights of each factor fuzzy consistency ratio (FCR) was calculated. The algorithm used in this research is borrowed from Chang (1996). The FCR is designed in such a way that if FCR < 0.10, the ratio indicates a reasonable level of consistency. However, if FCR is greater than 0.10 the value of the ratio indicates inconsistent judgments. The steps of the algorithm are as follows.

$$FCR = \frac{C_I}{R_I} \qquad CI = \frac{\lambda_{\max} - n}{n-1} \qquad \text{Equation 3.7}$$

$where, \lambda$ is average value of consistency vector and n is number of criteria.

3.4.3.4 Calculating Average Value of Consistency Vector

Calculating the average values of consistency vector or index ensures the logical relationship between the criteria presented. Furthermore, the value of this ratio should be as low as possible that indicating the relative comparisons have been made sensible. The process involves the calculation of several component parameters as follow.

Weighted Sum Vector (WSV)

In this case the first weight (w) is multiplied by the first column value in the matrix. The second by the second column and so on .These value are then summed over the rows to give WSV.

Consistency Vector (CV)

Here the WSV is divided by the criterion weight

Average Consistency Vector

This is the average value of the consistency vector (CV)

Table 3.6 Aaverage value of consistency vector

	0.510181	0.183665	0.102036	0.076527076	0.05612
	0.76713	0.25571	0.092056	0.06648459	0.038356
	0.63053	0.378318	0.126106	0.076924618	0.026482
	0.482566	0.275752	0.137876	0.068938045	0.042052
	0.35159	0.273459	0.195328	0.07813111	0.039066
Total WSV	2.741996	1.366904	0.653401	0.36700544	0.202076
WSV/Column (Consistency vector)	5.374561	5.345524	5.18137	5.323699567	5.17275

Average Consistency = 5.374561+ 5.345524+ 5.18137+ 5.17275 /5 = 5.279581

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$ = 5.279581-5/5-1= 0.0698

Calculating the Fuzzy Consistency Ratio (FCR)

$$FCR = \frac{C_I}{R_I}$$ =0.0698/1.12= 0.06

Where RI is random index that indicates consistency index of a randomly generated pair wise comparison matrix can be obtained from the table of random inconsistency. In this study the major criteria are 5 and the corresponding RI is 1.12. The FCR is designed in such a way that if $CR < 0.10$, the ratio indicates a reasonable level of consistency. However, if CR is greater than 0.10, the value of the ratio indicates inconsistent judgments. In this study FCR is 0.06 i.e FCR is less than 0.10 indicates a reasonable level of consistency.

3.5 Aggregation Method

According to Vladimir and Dmitry (2004) the spatial modeling in GIS passes four main steps among them aggregation phase is important. Once the criteria maps had been developed and the associated weights assigned to each input layer, aggregation stage was undertaken by using WLC in IDRISI software to combine the various factors. According to Hong and Ronald (2000), weighted linear combination (WLC) can be used as a fuzzy operator. Moreover, the factors of the analysis may not be equally important; hence, each individual criterion are reclassified into units of valuable and then multiplied them by a weight to assign relative importance to each and finally add them together for the final weight to obtain a land grade map. This can be conceptualized by the following equations.

$$F = \{f_l, f_2, f_i, \ldots\ldots\ldots\ldots, f_n\}$$ Equation 3.8

where, f_i, $i = 1, 2, \ldots . n$, represents each individual factor considered in the modeling process. Since the weight of each individual factor is different in the modeling process, we need to also represent the weight as another set;

$$W = (W_1, W_2, W_i, \ldots\ldots\ldots, W_n)$$ Equation 3.9

where, W_i, $i = 1,2, \ldots . n$, represents the weight of each individual influential factors.

$$L_g = \sum_{i=1}^{n} w_i * f_i$$ Where, L_g = land grade Equation 3.10

The WLC operator is adopted as the fuzzy operator in this research, because all of the evaluation criteria have been taken into consideration in a weighted manner, which is empirically consistent with the fuzzy modeling process in GIS.

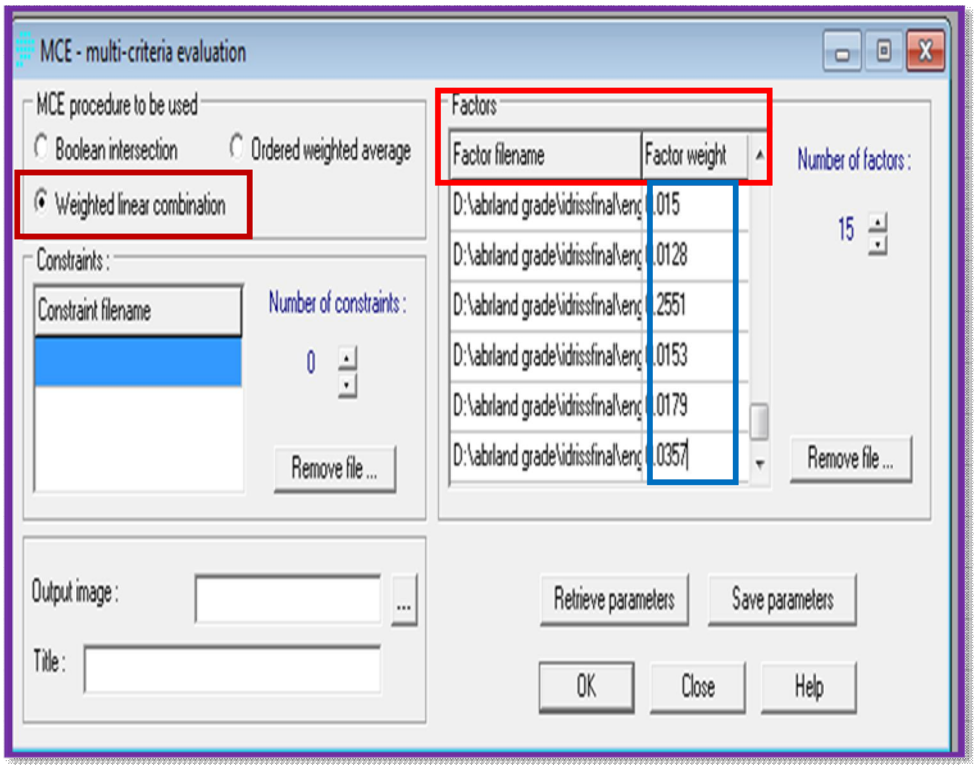


Figure 3.6 Sample aggregation methods by WLC in IDRISI

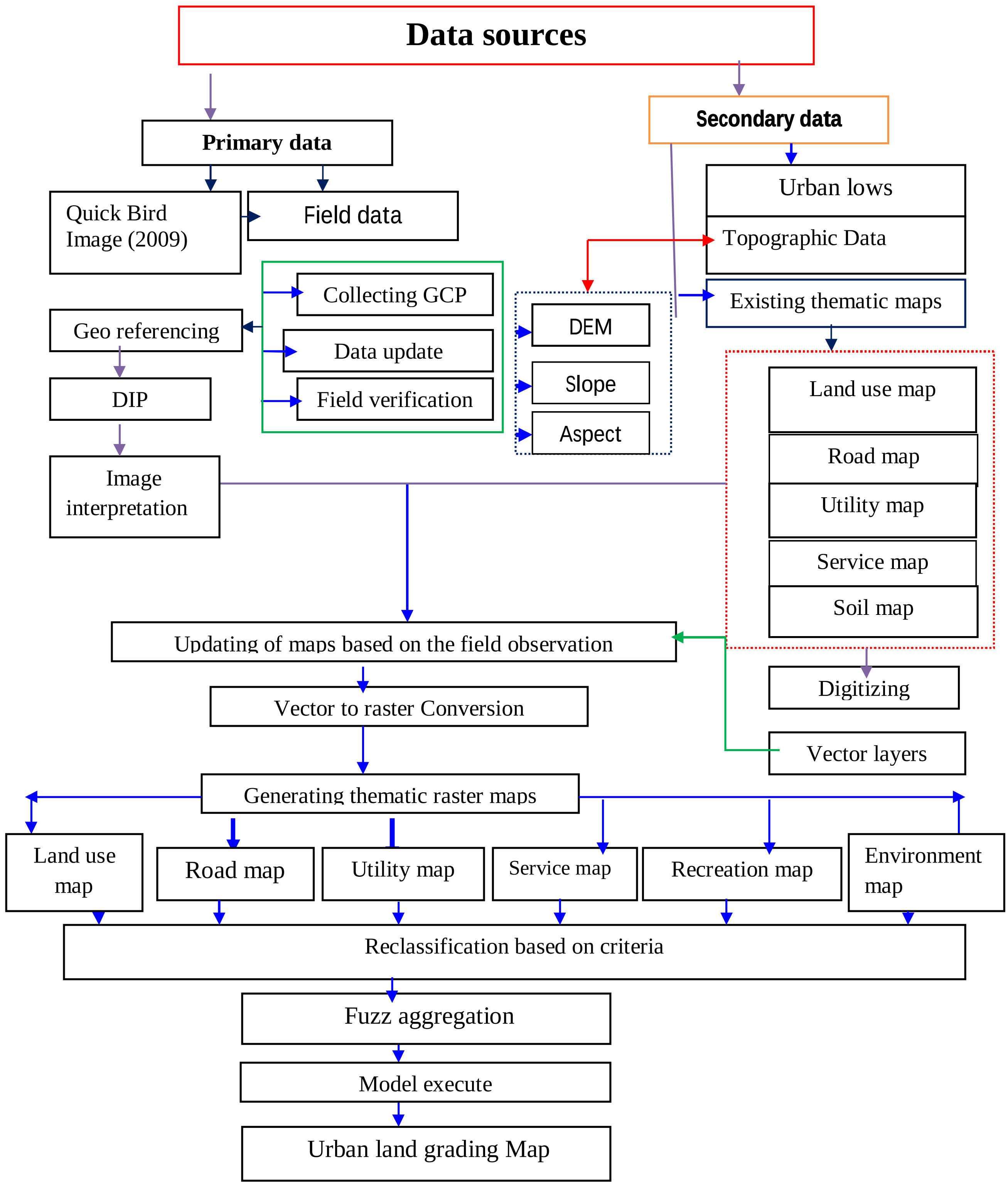


Figure 3.7 Summery of the conceptual model

3.6 Situational Urban Level Spatial Analysis

3.6.1 Analysis of the Significance of Urban Plans for Land Grading

According to urban planning proclamation No.574/2008, urban plans are a legally binding plan that sets out the basic requirements which could produce a coherent urban development in economic and spatial spheres. As per the evidence obtained from the officials of the municipality of the town, the development of Woldiya has been guided by more than two urban plans. The 1995 development plan prepared by the National Urban Planning Institute was used for more than ten years. The plan has served to guide the development of the town until the 2009 plan prepared by private consultants in partnership with the Regional Urban Planning Institute.

The general objectives of the plans were to bring integrated development of an urban area. More specifically the plan aims to establish a legal framework in order to promote planned and well developed urban centers and to regulate and facilitate development activities in urban centers and thereby enhance economic development of the urban locality. In Ethiopia, in conformity with a master plan of a city, urban land is permitted to be held by lease. For example, the Addis Ababa city administration has graded lease land and allocated initial prices as shown in Table 3.7

Table 3.7 Floor price of urban land in Addis Ababa by area and grades (Birr/M^2)

Grade	Center business zone	Transitional zone	Expansion zone
Grade one	1441	884	303
Grade two	1312	799	256
Grade three	1331	691	186
Grade four	948	583	163
Grade five	764	474	---

Source: ACCSA (2009)

From Table 3.7 it can be concluded that the most valuable land is located in the central business zone. The grading and lease price determination is based on the traditional Burgess land use models. However Burgess assumes a generalized geographic space and strict action space that explain it in the form of mono centric city. Furthermore, the important influential factors in land use change like topography and transportation system are not considered. In the Ethiopian context and particularly in the first and second level cities the mono centric city is unreasonable for representing real land use patterns.

3.6.2 Analysis of the Significance of Settlement Pattern for Land Grading

As different land economic literatures informed us, the urban land values are typically derived from a model of a mono-centric urban area with land rent as a function of household income and location rent. Woldiya town is a type of multi-centre town. Piassa , Adago and GonderBer have been supposed to be the centres of the present Woldiya town. Piassa has been the main centre of Woldiya since several years as it has been the junction of the main inter-town roads leading to Addis Ababa, Mekelle and Woreta.

During the field work, it is observed that the general built-up of the town is dominated by radial shape following the main existing roads and the suitable terrains for urban use. This shape has been formed due mainly to the search for road and other infrastructure services and the suitable terrains for residential settlement and related activities of urban use. This situation implies that the settlement characteristics are affected by the nature of topography and availability of infrastructure and services. As evidence, sites in the central business district (CBD) and sites along major highways are well provisioned in terms of basic infrastructure and utility services can be graded on the higher side compared to those with peripheral locations that lies along less important roads and in areas deficient in basic infrastructure.

Based on this fact, infrastructure provision can be consider as the basic determinant of land grade which has direct link to valuation and the process of price fixing for specific site characteristics.

3.6.3 Evaluation of the Existing Land Grade of Woldiya Town

Different efforts to guide development in Woldiya have been made since its foundation under the umbrella of the master plans. Among development tools urban land grading is in the front line. The last land grade system for Woldiya had been prepared in 1995. The process of preparation implementation of this land grade has its own strength and limitations. The following section presents the strength and limitation of the existing land grade system in the town.

Strength

The following are some of the strength and advantages of the existing land grading in Woldiya town.

- The existing land grade was used as land management tool and legal framework in order to regulate and facilitate taxation and town revenue system and thereby enhance economic development of the study area.
- It is used to establish benchmark prices on the lease of land and for the valuation of land related property.
- It is used to facilitate land marketing system that would facilitate investment.

Limitations

Despite the above strengths the existing land grade of Woldiya has not been very successful in allowing the town to benefit from the advantages of having an efficient land grading system. The major reasons behind the limitation on the effectiveness of the current land grade of the town emanates from the following factors;

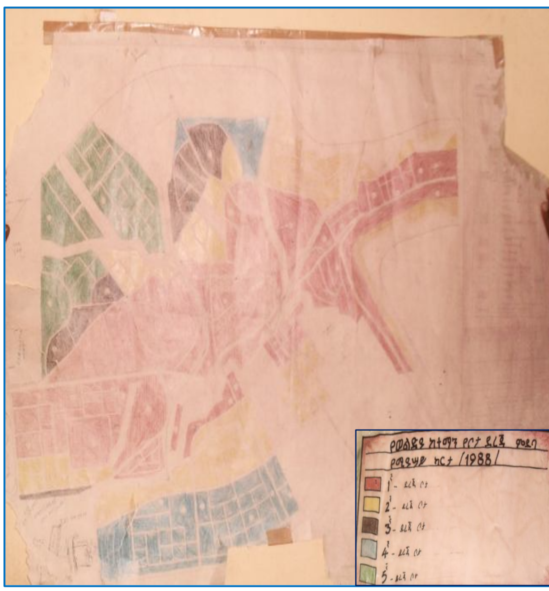
i) Technical Limitations

- It had been developed based on the classification of the town into four broad zoning categories (i.e. the CBD, intermediate zone, sub-urban and urban-rural fringes). This broad categorization and homogenization does not leave much room for capturing the real value of land.

- Major parameter for categorizing land into the above four broad zones had been mainly focused only on a mono-centric development.
- Major attributes that are of paramount importance in determining the suitability and accessibility and thus the grade of land, had been left out. Furthermore it did not take into account the implication of topographic slope which, in reality, do significantly affect the value of the land.

ii) Institutional Limitations

The existing land grade is not under regular supervision and there is no motivation to update based on specific time frame for its applicability.



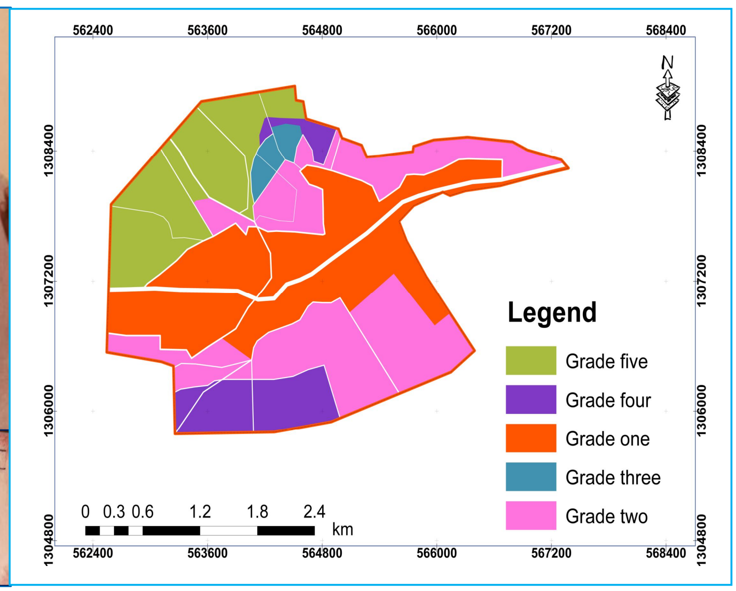


Figure 3.8 Scanned existing land grade Figure 3.9 Digitized existing land grade

Source : Woldiya town municipality

3.6.4 Analysis of Natural and Manmade Features of the Town

3.6.4.1 Topography

During the field work, it was observed that the nature of the land of the town of Woldiya is rolling, hilly and mountainous. The existing built-up area of the town is situated on the rugged topography. Topography/ surface slope is one of the most important elements for impacting urban and rural development and construction which not only affects the spatial structure within the city layout, but also to the economic investment and engineering measures (Luo *et al.*, 2008).

For example, Ethiopian local urban planning manual considers the settlements on or near cliffs is not suitable for housing development. It also recommend to be used as urban green frame for ecological protection because such elevated area are difficult for the provision of urban infrastructure development particularly supplying such areas by facilities like roads, water supply, electricity and so on are much more costly in comparison to the flat areas. Practically, this would mean that the development of the high slope land would require considerable inputs (finance, manpower, materials and time etc) and thus may be less valuable as against the flat land where the inputs required are considerably less.

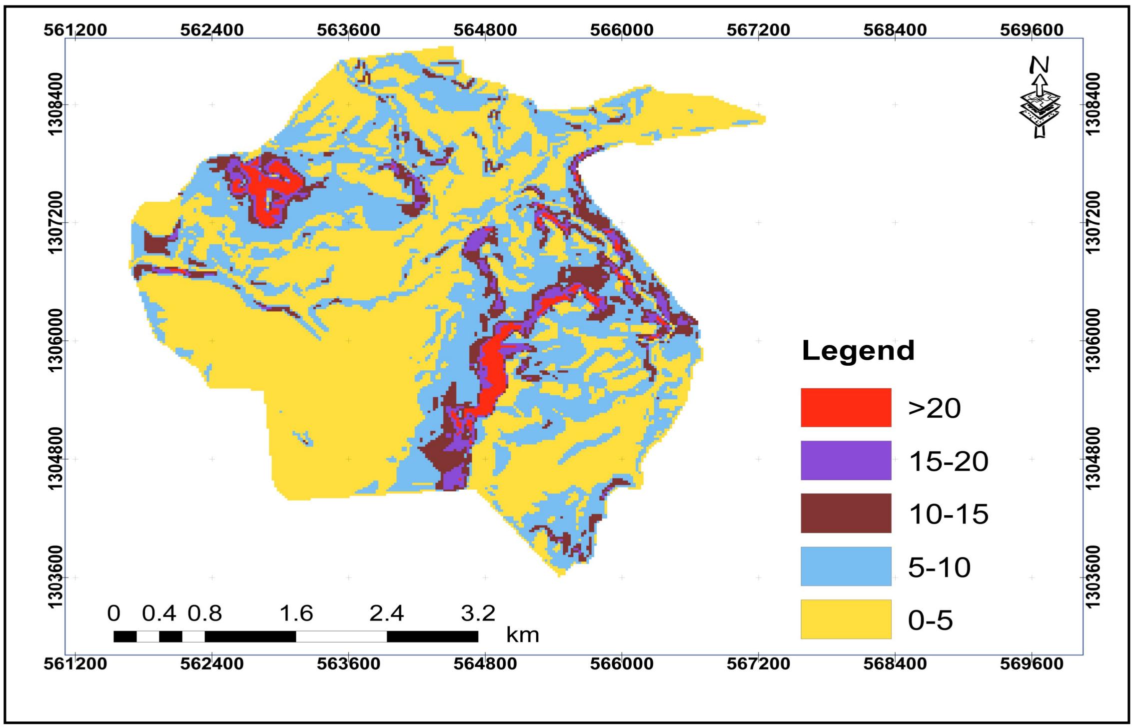


Figure 3.10 Classified slope of the town in degree

Source: Computed from Woldiya two meter contour

3.6.4.2 Natural Constraints

Presence of Mountainous Area

Woldiya town and its surrounding areas are characterized by the presence of high mountains such as Adengur and Gubarja in the east and small mountains Kubi Kalo and Guba Lafto/ Tekle Haimanot in the west and south respectively. The mountains have capacity to obstacle the expansion of the town particularly in eastwards.

Presence of Streams

Many parts of the town coupled with the nature of topography are exposed to erosion, gully formation and flood problem for its loosely held soil. Large numbers of gullies that dissect the various parts of the town are emerging. They have been obstacles to integrate the different parts of the town. During the field it is observed that streams in the town are neither used for recreation nor are inputs for production. The economic cost of allocating land on river banks is pollution caused by open dumping. This condition has its own negative impact in the quality of the land or suitability of the land for different urban development activities.

3.6.4.3 Analysis of the Land Use Plan

The land use plan is the main component of master plan (Urban planning implementation manual, 2006). Therefore, analysis of urban land use classes goes back to analysis of master plan. Land use classes are structured hierarchically according to their application fields and levels. For instance, in terms of general land use, urban land can be classified as urban built-up area and non-urban area. For town planning purpose, it can be classified as residential, commercial, industrial, road, park and other public green space etc (Qingming *et al.,* 2000). Accordingly, as can be seen in Figure 3.11 and Figure 3.12, the town's land use is divided into ten sub-categories, i.e. residence, commerce, administration, services, green areas and recreation, industry and warehouses, road and transport, agriculture, forest, and special function.

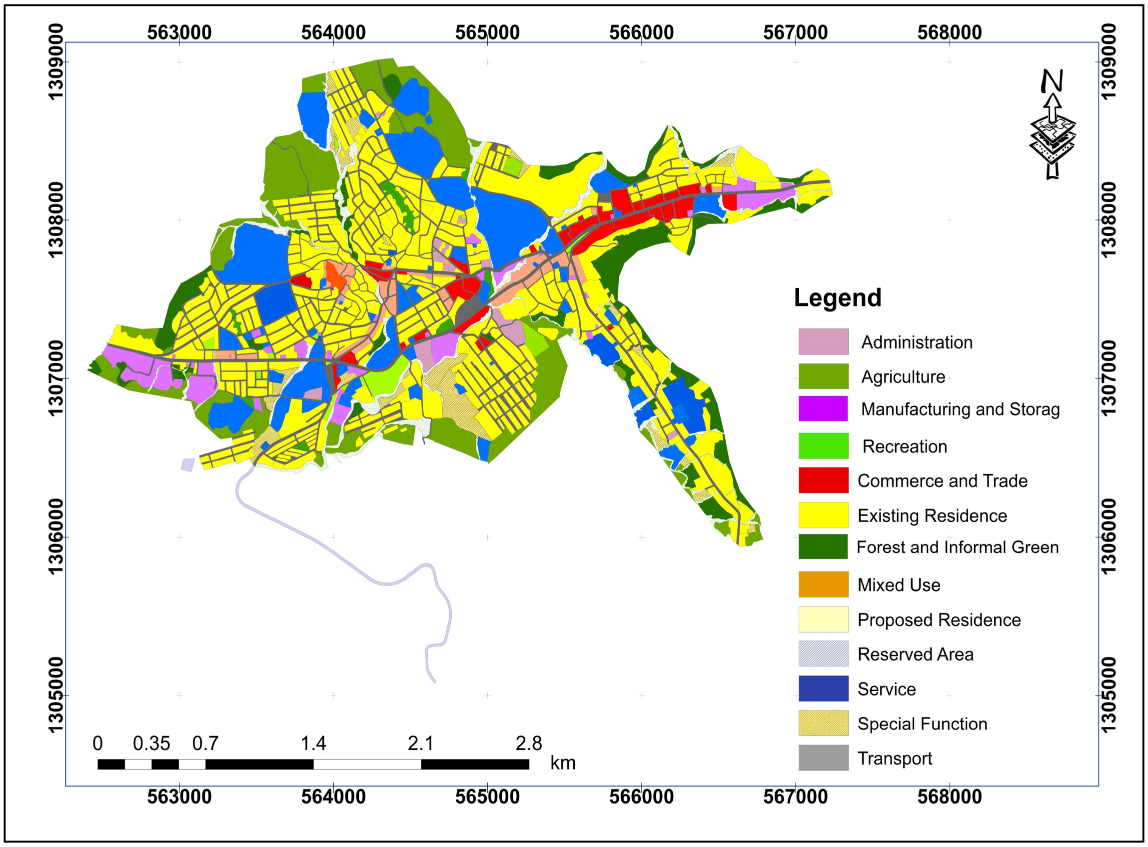


Figure 3.11 The 1995 master plan of Woldiya town
Source: Prime Consultants Plc

As illustrated in Figure 3.11 the patterns of commercial land use decreases as we go from inner to outskirt of the town. Furthermore, the overall settlement and dynamics of urban land use is mainly influenced by road development. The land use pattern supports the mix of concentric zone and sector model in that commercial activities appear clustered near the town center followed by manufacturing and residential uses.This pattern has been formed due mainly to the search for road and other infrastructure services and the suitable terrains for residential settlement and related activities of urban use. This situation implies that the settlement characteristics are affected by the nature of topography and availability of infrastructure and services. As depicted in Table 3.8 residential land use occupies the largest portion of urban land use while the distribution of commercial area is limited as compare to residential area. This implies that the town was not commercially vibrant.

Table 3.8 Land use by categories and area of Woldiya town (1995)

S/N	Land use categories	statistics of land use (1995)	
		Area (in ha)	Percent
1	Residence	280.52	42.5
	- Pure residence	249.74	
	- Mixed	30.78	
2	Commerce	63.05	7.5
3	Administration	13.21	2.0
4	Service	93.63	14
5	Recreation	13.55	2.0
6	Road and transport	89.43	13.5
7	Manufacturing	12.96	2.0
8	Forest	67.90	10.3
9	Agriculture	1.49	0.2
10	Special function	24.92	3.8
Total		660.66	100%

Source: Computed from Woldiya master plan of 1995

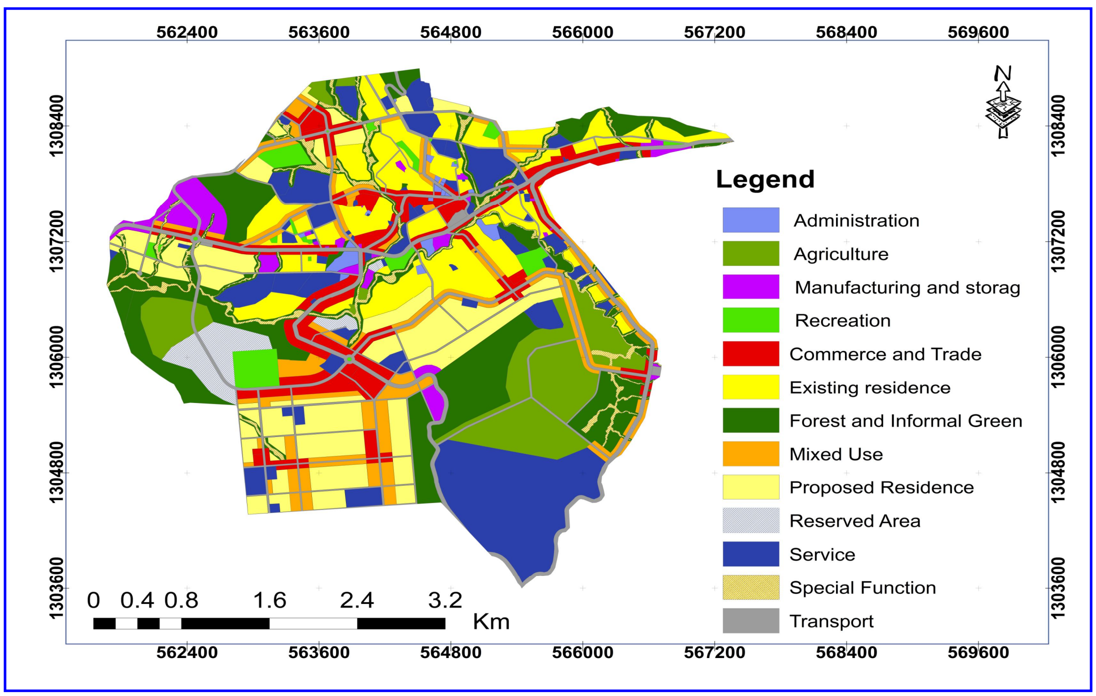


Figure 3.12 The 2009 master plan of Woldiya town

Source: Prime Consultants Plc

The 2009 master plan of Woldiya was prepared to transform the town from being mono-centric to a multi-centric urban area in order to decentralize the population and economic activities (master plan report, 2009). As can be seen in Figure 3.12, the master plan of Woldiya has brought significant change as compared to the 1995 master plan (Fig 3.11). The spatial coverage, the creation of centers and expansion of commercial colliders along the major arterial roads are some of the manifestation of the spatial land use change that have in turn influence in land value and land grading.

Table 3.9 Land Use by categories and area of Woldiya town (2009)

S/N	Land use categories	Area (ha)	Percent
1	Residence	605.77	32.548%
	- Pure residence	481.88	
	- Mixed	123.89	
2	Commerce	136.66	13%
3	Administration	14.53	0.772%
4	Service	283.33	15.04%
5	Recreation	39.98	2.1%
6	Road and transport	190.57	10.10%
7	Manufacturing	55	2.9%
8	Forest	306	16.26%
9	Agriculture	154.91	8.18%
10	Special function	93	4.9%
Total		1,881.06	100%

Source: Computed from Woldiya master plan of 2009

As depicted in the Table 3.9, residence takes the major's share (33%) of the total area of the town .The share for service is also important (about 15 percent) this is due to the existence of Woldiya University which has about 126 ha of land. As usual, commercial activities are mainly concentrated in centres and sub-centres of the town. Most of the areas adjacent to both sides of the main road leading to Mekelle in Piassa those areas north and south of the bus terminal in Adago, and the road leading to Addis Ababa and Gondar Ber are mostly used for commercial services and activities.

Most of these activities include hotels, bars, groceries, restaurants, bars and boutiques of textiles, building materials, electronic equipments, barberries, etc. This indicates that in general compared with other land use types commercial land use values are the most centralized and with higher values in the downtown area and decreasing quickly with the increase of distance from the central business district. This type of development matches with urban land use theory that states, land values declines as distance increases from the city centre (http://www.uncc.edu./hscample/land value/b-model/c-bidrent.html).

3.6.4.4 Urban Land Use Change (Trend, Rate and Magnitude)

An important aspect of urban land use change analysis in urban planning is to determine what is actually changing to what and which land use is changing to the other function. In this case, to understand how urban land use is spatially and functionally changing, one can get sufficient evidence by comparing the two master plans. For example, from the master plan of 2009, at the NW there is a significant conversion from residential to commercial land use. The inner part of the town is predominantly of commercial land use function. Furthermore, mixed activities are also found along the main roads, i.e. along the major roads of Addis Ababa and Mekelle. In addition to the area indicated for commerce, it is important to take note that mixed residential activities are usually located in the areas found between the zones designated for commercial and residential activities. As shown in the Figure 3.12, mixed residences have been allocated in the centers (main centre, sub-centre and tertiary centers) and along major streets of the town. This indicates that there is land use change so is land grade and its bench mark price. Generally, as it can be seen in Table 3.10 all the land use categories have shown positive change. This implies that the town has grown spatially at increasing rate in the given period of time (1995-2009).

Table 3.10 Urban land use function statistics of Woldiya town (1995-2009)

S/N	Land use categories	Area coverage of each land use		Change in percent (2009-1999)
		Master plan of 1995	Master plan of 2009	
1	Residence	280.52	605.77	+26.65
	- Pure residence	249.74	481.88	
	- Mixed	30.78	123.89	
2	Commerce	63.05	136.66	+6.03
3	Administration	13.21	14.53	+0.11
4	Service	93.63	283.23	+15.53
5	Recreation	13.55	39.89	+2.16
6	Road	89.43	190.57	+8.29
	- Road		188.01	
	- transport		2.56	
7	Manufacturing & warehouses	12.96	55.52	+3.49
8	Forest	67.90	306.60	+19.56
9	Agriculture	1.49	154.91	+12.57
10	Special function	24.92	93.38	+5.61
Total		660.66	1,881.06	

Source: Computed from Woldiya master plan (1995- 2009)

3.6.4.5 Infrastructure Analysis

Introduction

It is common trend that potential users determine the utility they would derive from the land based on; whether there is adequate infrastructure service for direct use (e.g. education and health) and whether there is adequate infrastructure or service that will make the land more accessible (e.g. public transport and road). Depending on the availability or accessibility of these infrastructure and services, users will attach a certain value to the land. Here it is important to note that the quality and value of the urban land depend on the urban infrastructure systems of the town. Being the road network has capacity to give a clear picture of the existing situation of infrastructure and related issues the detail analysis of road network and the center and sub center of the town is given due attention.

Road Network

Urban road networks provide the primary means of transportation for city, social and economic activities (Mostafa, 2011). During the field work it is observed that the town is composed of different hierarchy of roads which includes major arterial roads, sub-arterial roads (secondary roads) collector streets and local streets (Fig. 3.13).

Major Arterial Roads

The roads that link the town with other urban and rural areas is continuing to be major arterial roads of the town. The roads of the town that have been studied as major arterial roads are along Addis Ababa, Mekelle and Gondar. The size of right-of-way is 40m in dimension (Fig. 3.13).

Sub-Arterial Streets (Secondary Roads)

The roads of the town that have been identified as sub-arterial are considered to link the different parts of the town and its surrounding areas. It is linked to major arterial roads. These roads have right-of-ways ranging from 24m to 30m (Fig. 3.13).

Collector Streets

The streets that are considered as major collector are actually those connecting the different parts of the town. There are, in this case, collector streets that play the role of connecting the recent expansion areas with that of the town's existing built-up areas. Minor collector streets are proposed to link the different streets of minor collector level with the intention of distributing travel to local streets and on the other hand, to collect travel from local streets to major collector streets are all grouped under minor collector streets. During the data collection it is observed that most of the streets of both major and minor collector levels are not with proper surfacing materials.

Local Streets

The local streets are designed to provide local access in a given neighborhood. The specific land use block is commonly determined by the local streets. These streets have right-of-ways ranging from 6m to 8m.

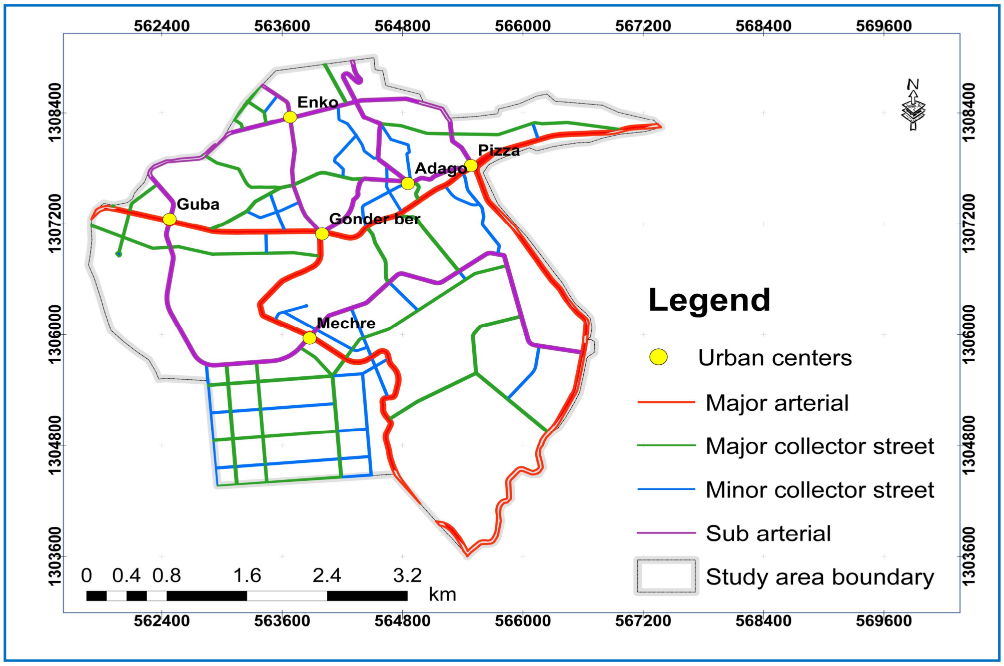


Figure 3.13 Road net work hierarchy of the town
Source: Prime Consultants Plc

Main Centers of the Town

Currently, Woldiya is being transformed from mono-centre town to multi center town. Piaza and Adago are considered to be the main centers of the present Woldiya town. Piassa has been the main centre of Woldiya since several years as it has been the junction of the main inter-town roads leading to Addis Ababa, Mekelle, and Woreta. The centrality of Piassa has been still maintained. This is due to its importance as a junction and its commercial importance due to the existence of hotels, bars, restaurants, shops and financial institution.

Sub-Centres of the Town

According to the observation made during the land use inventory, there are two sub-centers emerging in the town. The first is found in Gondar Ber where the Addis Ababa-Mekelle and Woldiya-Wereta main roads meet; the second is Mechare where the new stadium is constructed. Guba and Enko are also considered as one of the centers in the near future.

3.7 Criteria Description and Preparation

3.7.1 General Description

Different researchers like Saba *et al.,* (2011), suggested that the selected criteria should be relevant to the analysis and also the selection process has to be tailored to the needs of the problem at hand and be based on the characteristics of the system that is analyzed. In this study, twenty four criteria were used for designing conceptual fuzzy land grade. They fall into five main categories which includes infrastructure, land use, topography, environmental visual quality and population density. In determining the value given to each criteria and in establishing the level of desirability of each attribute, different measurements and ranges have been used where most applicable to existing national norms and standards.

Data processing and analysis of all factor maps were done in the Arc GIS and IDRISI software. Distance maps have been generated by using the spatial analyst straight line distance function in ArcGIS which creates such maps by calculating the straight line (Euclidean) distance from the identified criteria. The "RECLASS" function was then used to determine the grading zones.

3.7.2 Creating Factor Maps

According to Afzali *et al.* (2011, as cited in Mahini and Gholamalifard, 2006) factor is a criterion which causes the suitability of an alternative increase or decrease for a specific application. Based on the affirmed concept, the following section presents the criteria used in this study area.

Slope Factor Map

The study has examined the characteristics of topography with respect to slope and analyzed their implications in urban land grading. As indicated in Table 3.11, the available land is under different topographic classes and it can be inferred that about 20% belongs 0-10 degrees which is suitable for urban infrastructure development. On the other hand, about 20% of land belongs to 20 degree and above which is considered difficult for urban infrastructure development.

Table 3.11 Slope classification and area coverage

Slope in Degree	Area (ha)	Percent share
0-5	7.6	4.3
5-10	28.5	16.1
10-15	54.0	30.5
15-20	53.3	30.1
>20	33.7	19.0
		100 %

Distances Maps

The distances to roads, education facilities, health facilities, transport facilities, recreation and civic centres, market area and commercial activities are some of the important criteria used in determining the urban land grading of the study area. Their maps have been created by using the Spatial Analyst Straight Line Distance function in ArcGIS which creates such maps by calculating the straight line (Euclidean) distance from centre of site (roads, education facilities, health facilities, transport facilities, recreation and civic centres). The result is a raster dataset in which every cell represents the distance to the main facility centre in meters.

Distance to Roads

Based on the existing road hierarchy three type of road (main road, sub arterial and collector roads) are used as input criteria for designing the conceptual model (Fig. 3.14-Fig. 3.19).

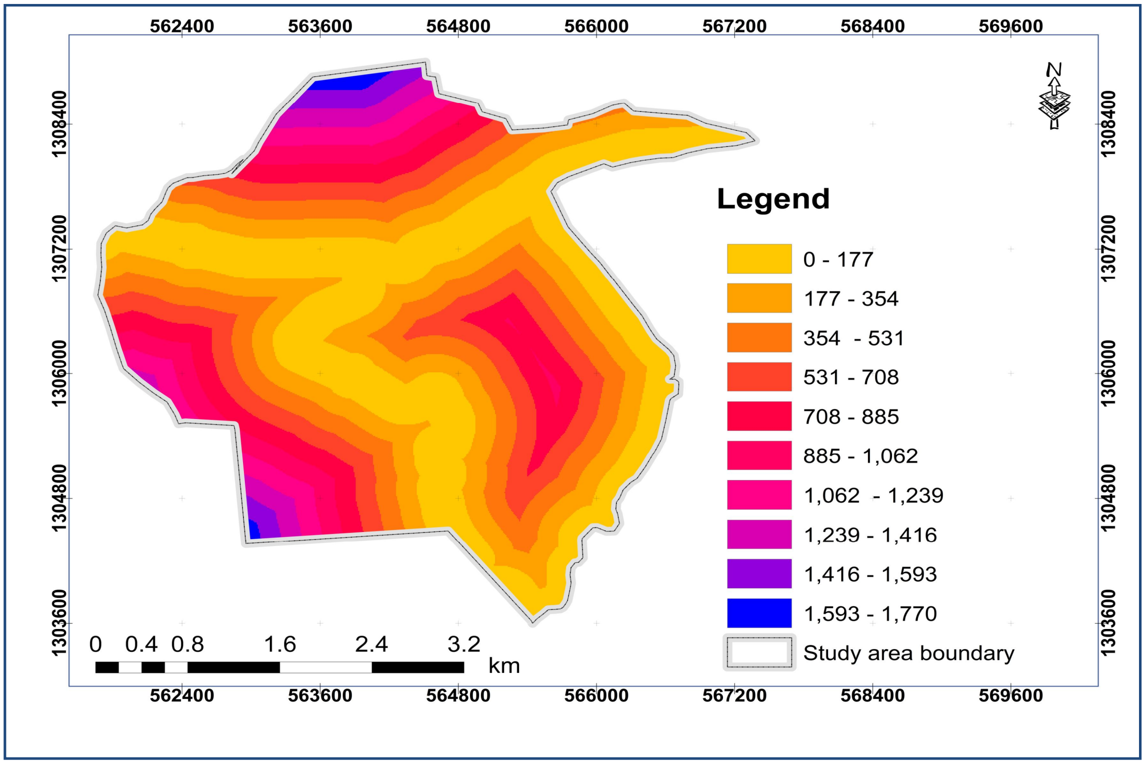


Figure 3.14 Distance to main roads (meters)

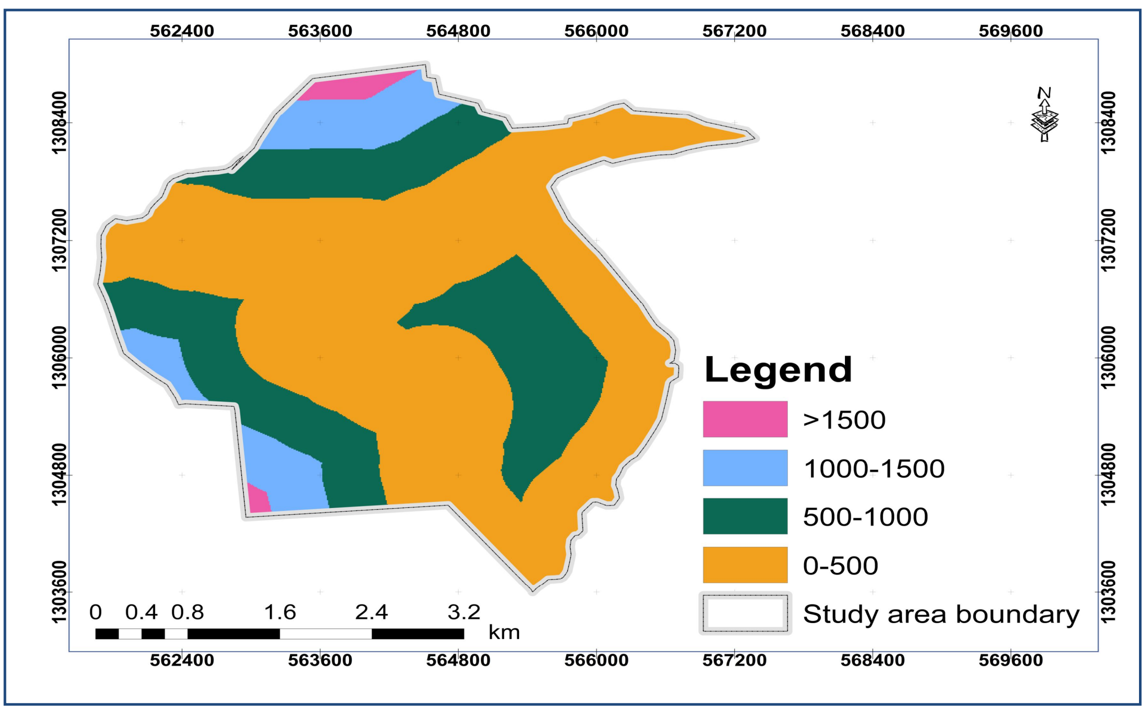


Figure 3.15 Reclassified main roads (meters)

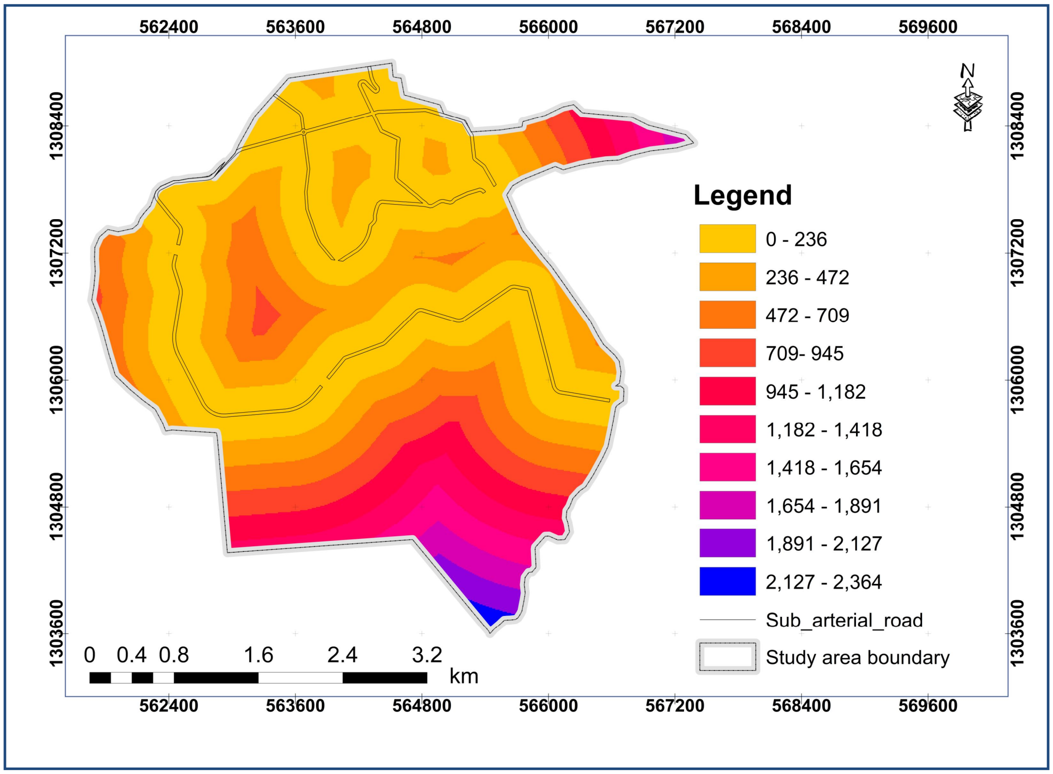


Figure 3.16 Distance to secondary roads (meters)

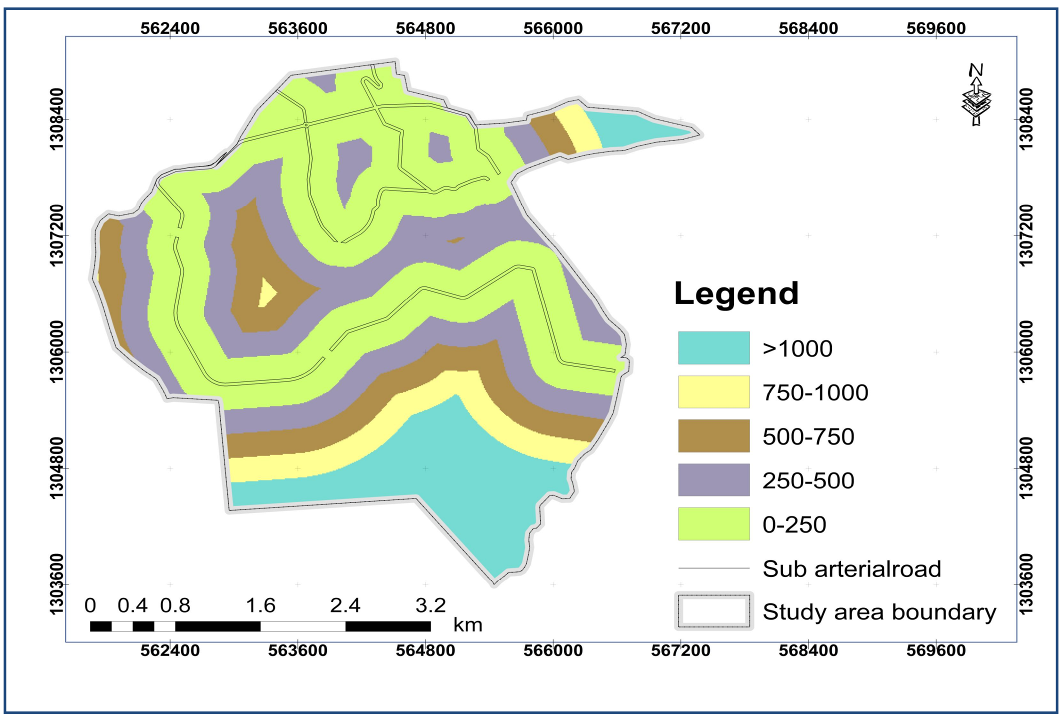


Figure 3.17 Reclassified secondary roads (meters)

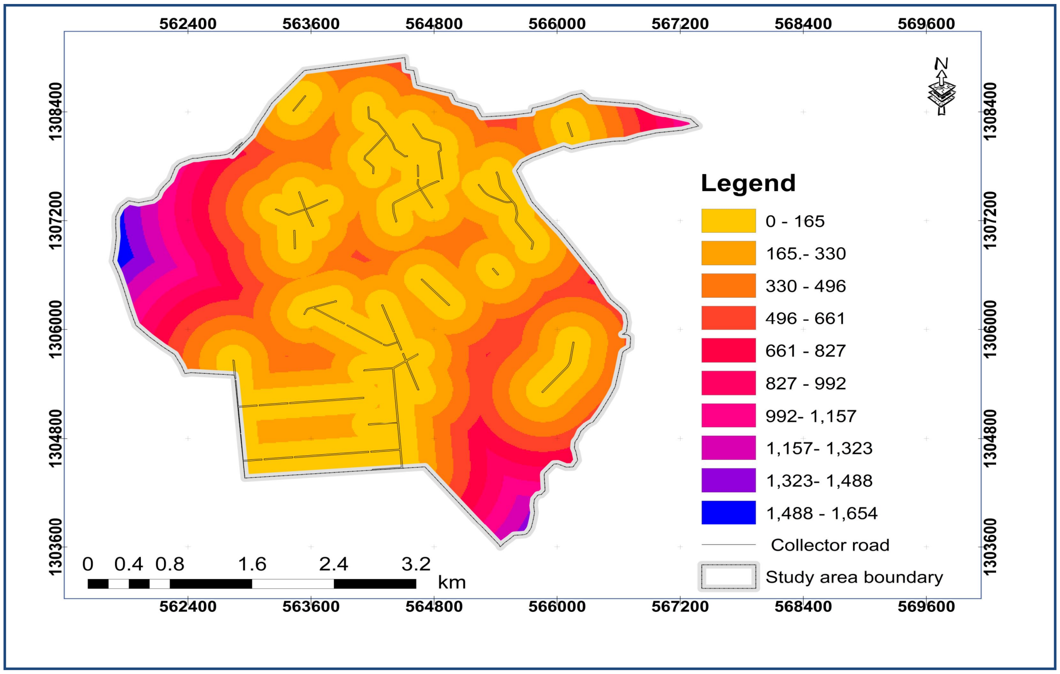


Figure 3.18 Distance to collector roads (meters)

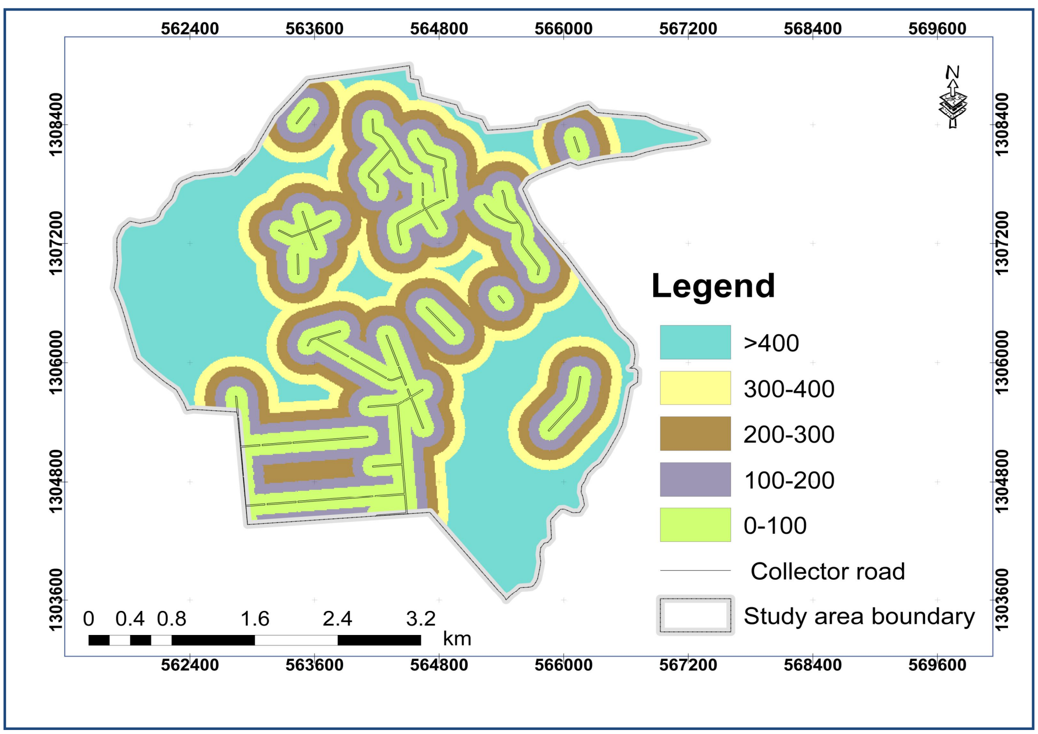


Figure 3.19 Reclassified collector road (meters)

Table 3.12 Summery reclassification of the road criteria

Hierarchy	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Main road	0-500	500-1000	1000-1500	1500-2000	>2000
Secondary road	0-250	250-500	500-750	750-1000	>1000
Collector road	0-100	100-200	200-300	300-400	>400
CBD	0-500	500-1000	1000-1500	1500-2000	>2000

Distance to Education Facilities (university, high school and primary school)

Living area which is near to educational institution is favorable choice for citizens and availability of educational facility is assumed to increase the quality of the neighborhood. In this study, the availability and accessibilities to educational institutions were considered as one main factor for designing land grade. Here, Euclidean distance from the main education facilities (university, high school and primary school) was used as input for the land grade. Figure 3.20- Figure 3.22 shows the criteria map of educational facilities.

Table 3.13 Summery reclassification of the educational criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
University	0-1500	1500-3000	3000-4500	4500-6000	>6000
Secondary school	0-1250	1250-2500	2500-3750	3750-5000	>5000
Primary school	0-1000	1000-200	2000-3000	3000-4000	>4000

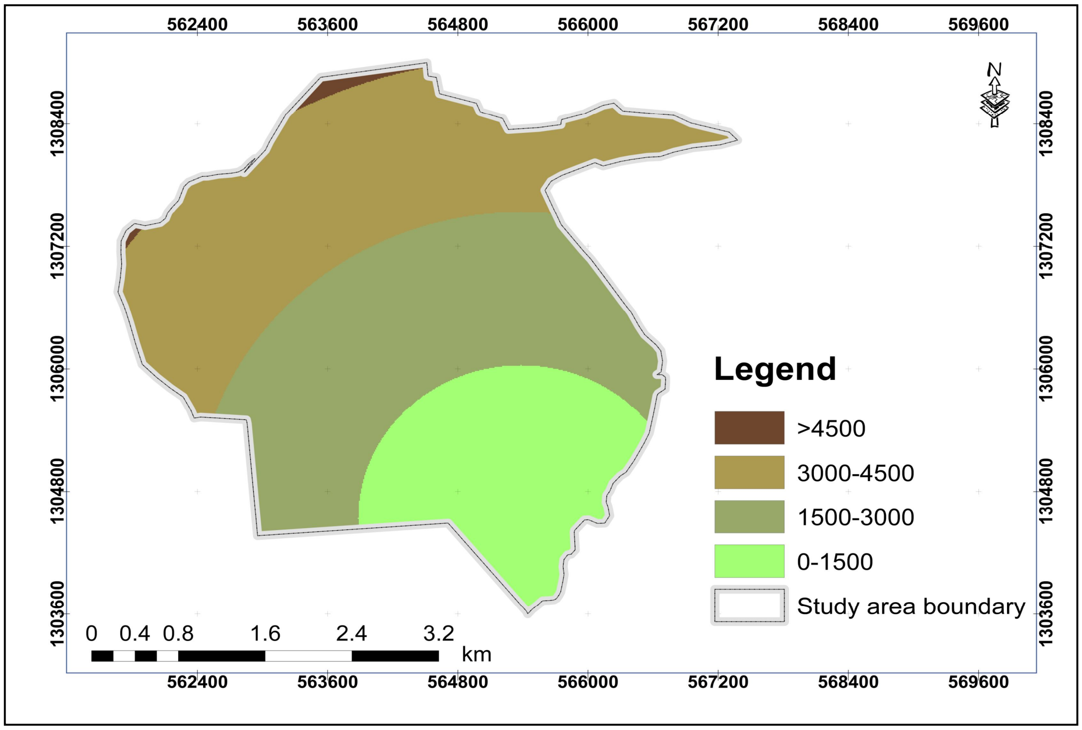


Figure 3.20 Reclassified University (meter)

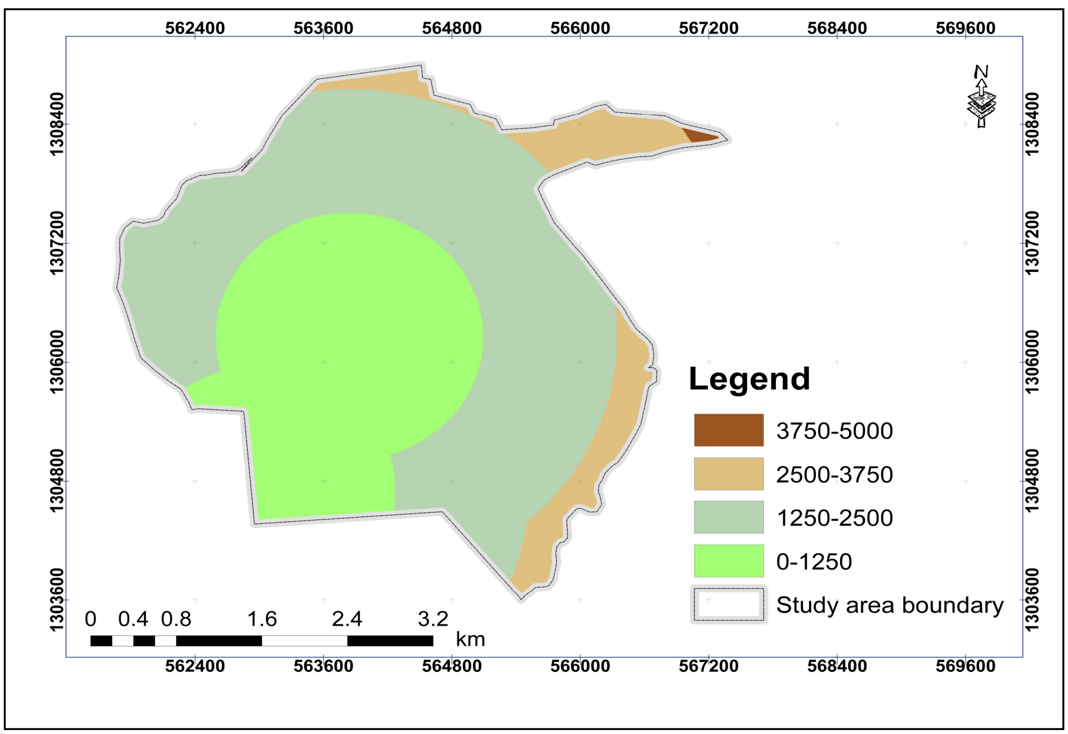


Figure 3.21Reclassified high schools (meter)

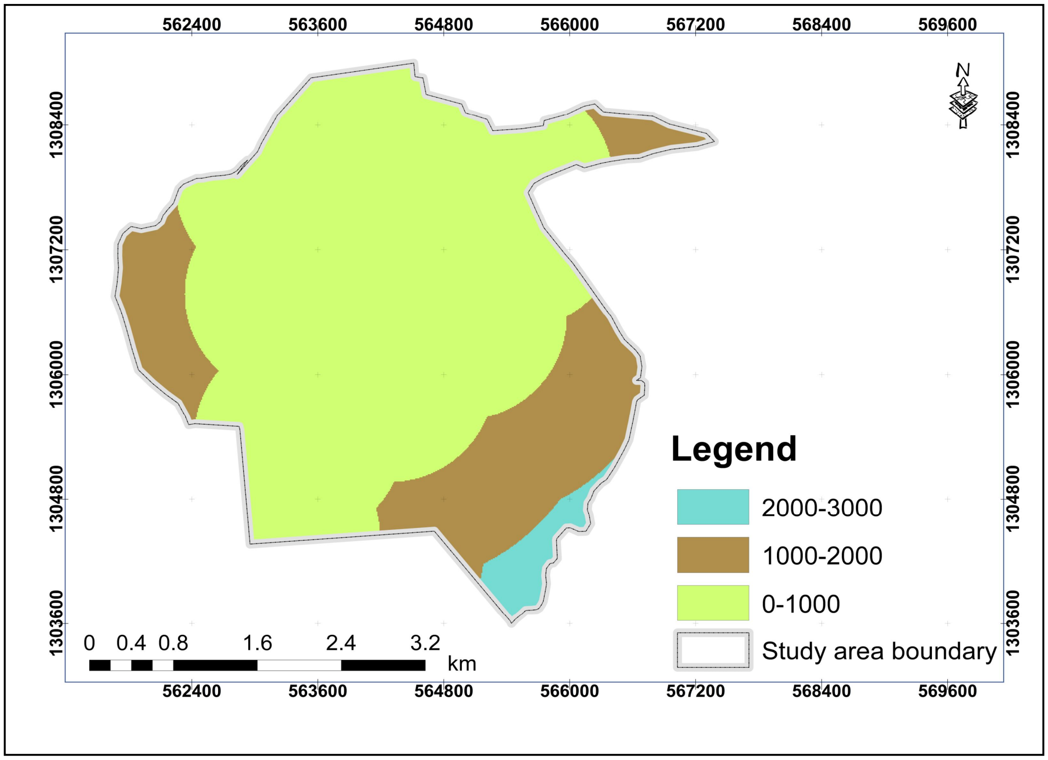


Figure 3.22 Reclassified primary schools (meter)

Distance to Health Facilities (distance to hospital and health center)

Availability of a health facility at close proximity that can provide at least adequate emergency health services and the existence of different levels of health facilities increase the location value of land to the user. Figure 3.23- Figure 3.24 shows the criteria map of health facilities.

Table 3.14 Summery reclassification of health criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Hospital	0-1500	1500-3000	3000-4500	4500-6000	>6000
Health centre	0-500	500-1000	1000-1500	1500-2000	>2000

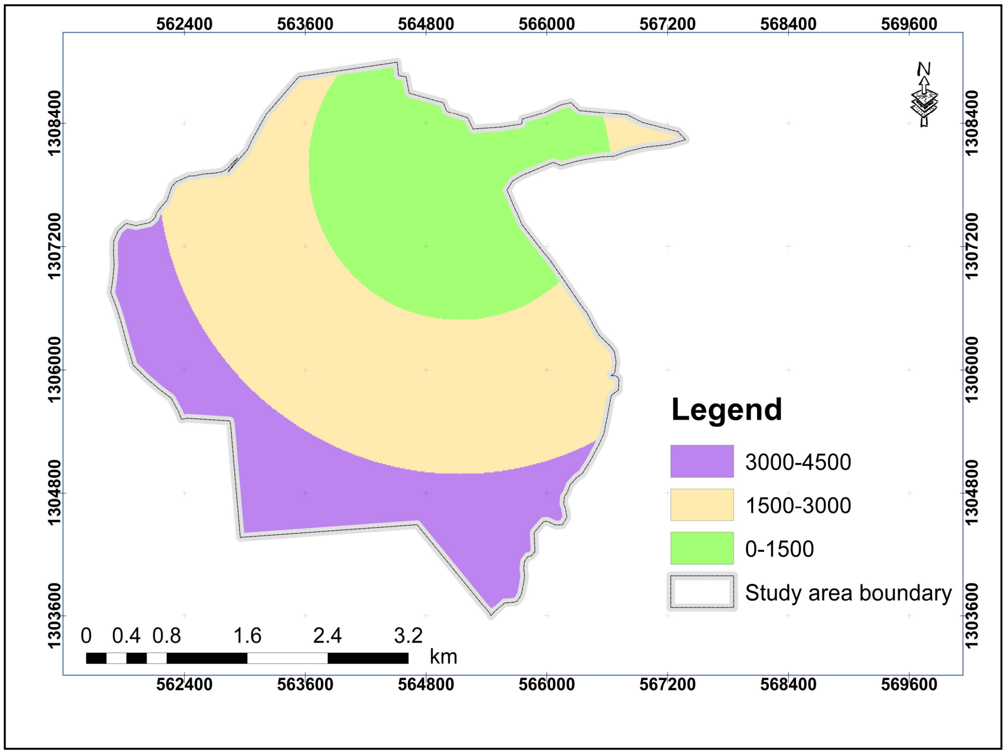


Figure 3.23 Reclassified Hospital (meter)

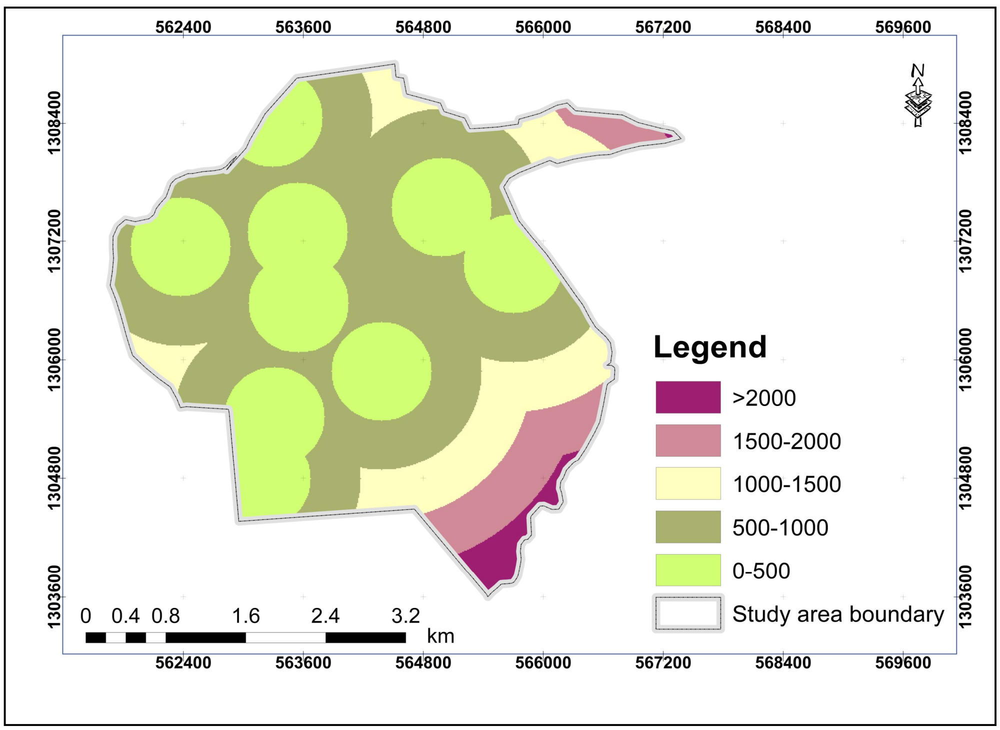


Figure 3.24 Reclassified health centre(meter)

Distance to Entertainments (distance to youth centre and sport centre)

Sport centers and youth centers have potential to make places comfortable to live, play and visit. For example, close proximity to accessible recreational centre can be one criterion to attract potential investors and developers that have capacity to improve the site characteristic.

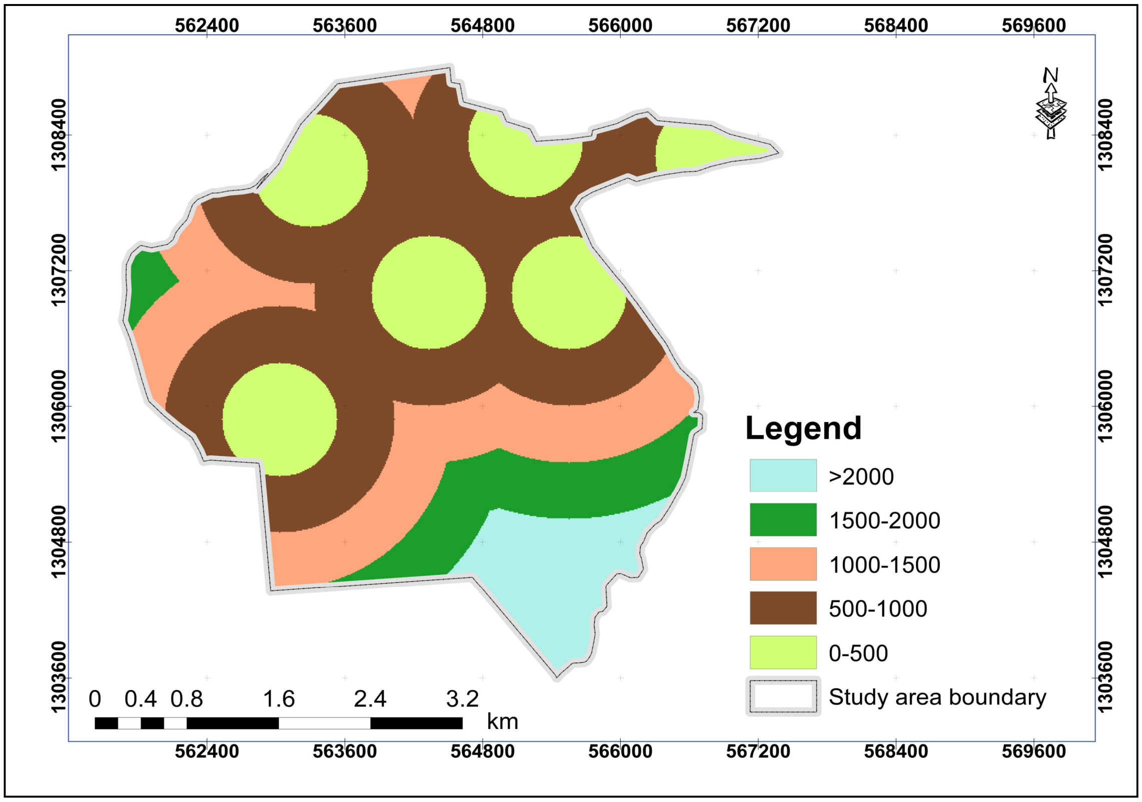


Figure 3.25 Reclassified sport centre(meter)

Table 3.15 Summery reclassification of recreation criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Youth centre	0-500	500-1000	1000-1500	1500-2000	>2000
Sport centre	0-500	500-1000	1000-1500	1500-2000	>2000

Distance to Security (distance to administration and distance to police station)

Close proximity to a local administration station implies reduction in transport expenses for households in travelling for justice. In addition, individuals may feel secured if there is police station nearby that they frequently can report for any unsecured event.

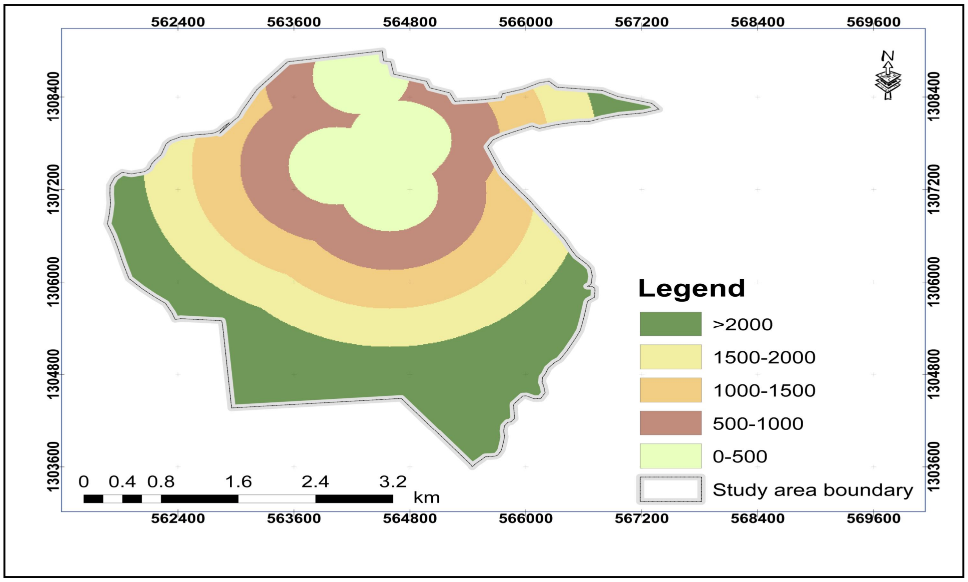


Figure 3.26 Reclassified local administrations(meter)

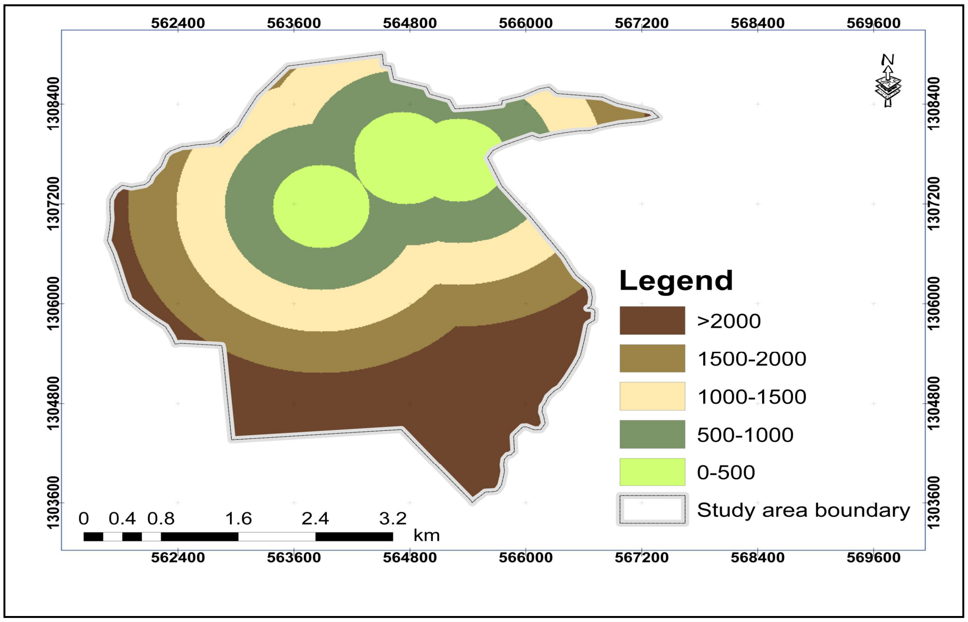


Figure 3.27 Reclassified police stations (meter)

Table 3.16 Summery reclassification of security criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Local administration	0-500	500-1000	1000-1500	1500-2000	>2000
Police station	0-500	500-1000	1000-1500	1500-2000	>2000

Distance to Public Facilities (distance to post office and sector offices)

Nearness to public facilities is assumed to increase accessibility of household to get proper public service delivery facilities. Some of the facility considered in this case include; distance to sector offices (telecommunication, electricity, water supply office) and distance to post office.

Table 3.17 Summery reclassification of public facilities criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Sector office	0-1000	1000-2000	2000-3000	3000-4000	>4000
Post office	0-1000	1000-2000	2000-3000	3000-4000	>4000

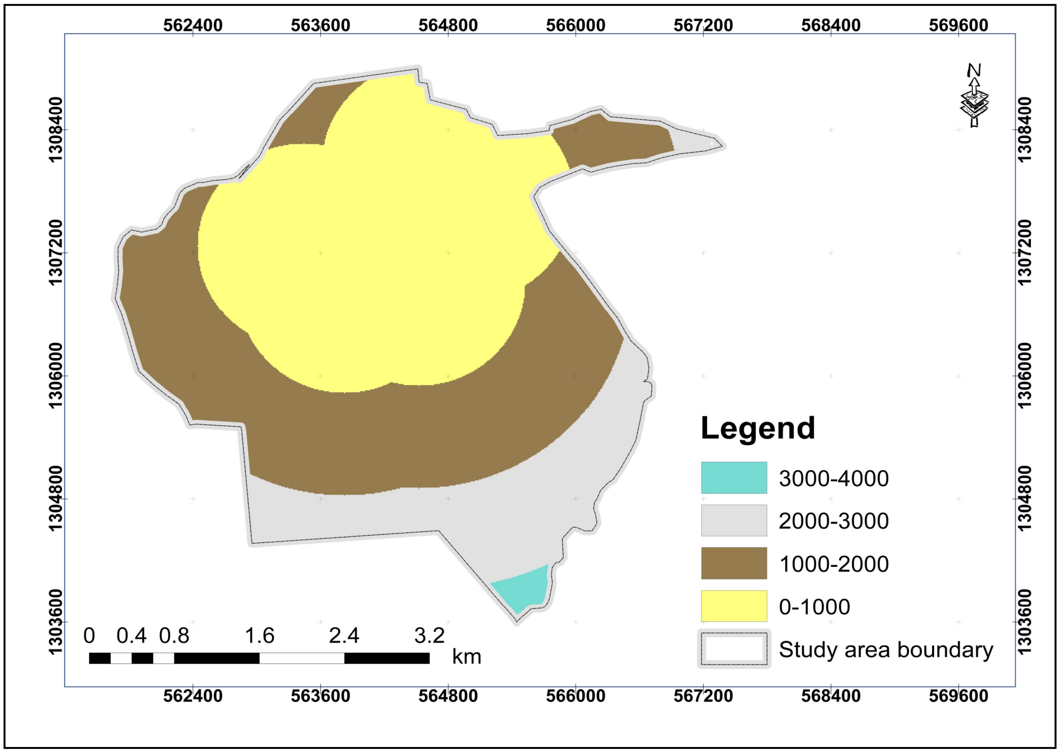


Figure 3.28 Reclassified post offices (meter)

Distance to Commercial Centers

Closeness to commercial colliders, market centers, shopping malls and supermarkets offers a great convenience to potential buyers which translate to higher perceived values. It is common trend in towns and cities that real estate developers are willing to pay first-class price for location with great accessibility and commercial amenities.

Table 3.18 Summery reclassification of commercial centers criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Commercial clusters	0-150	150-300	300-450	450-600	>600
Market place	0-500	500-1000	1000-1500	1500-2000	>2000

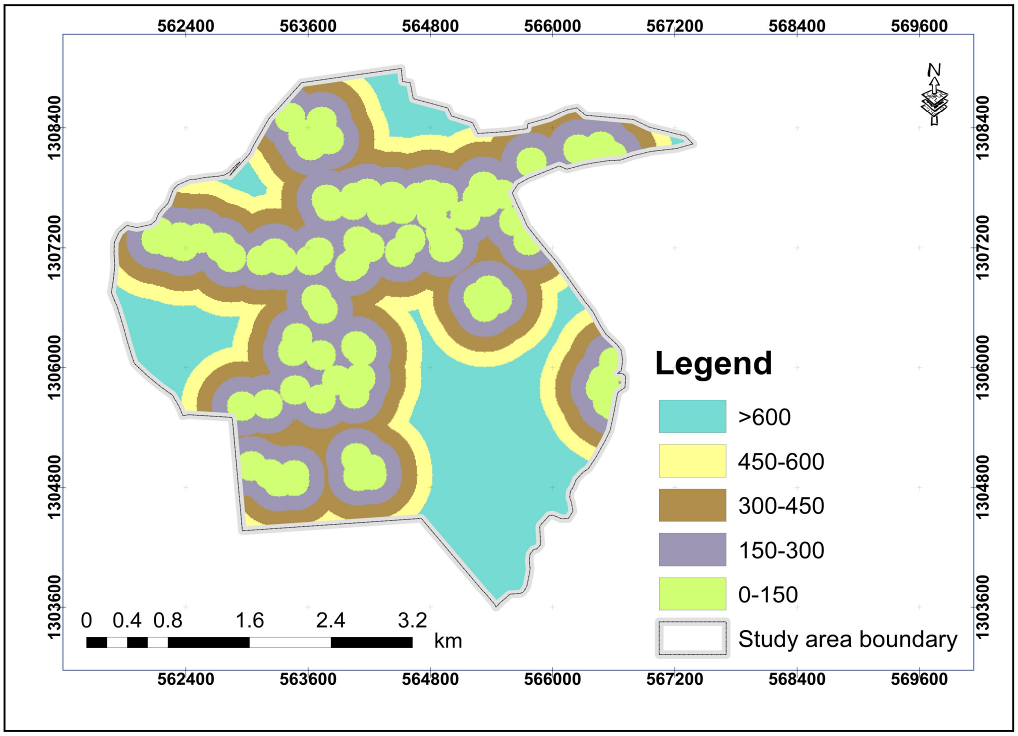


Figure 3.29 Reclassified commercial colliders (meter)

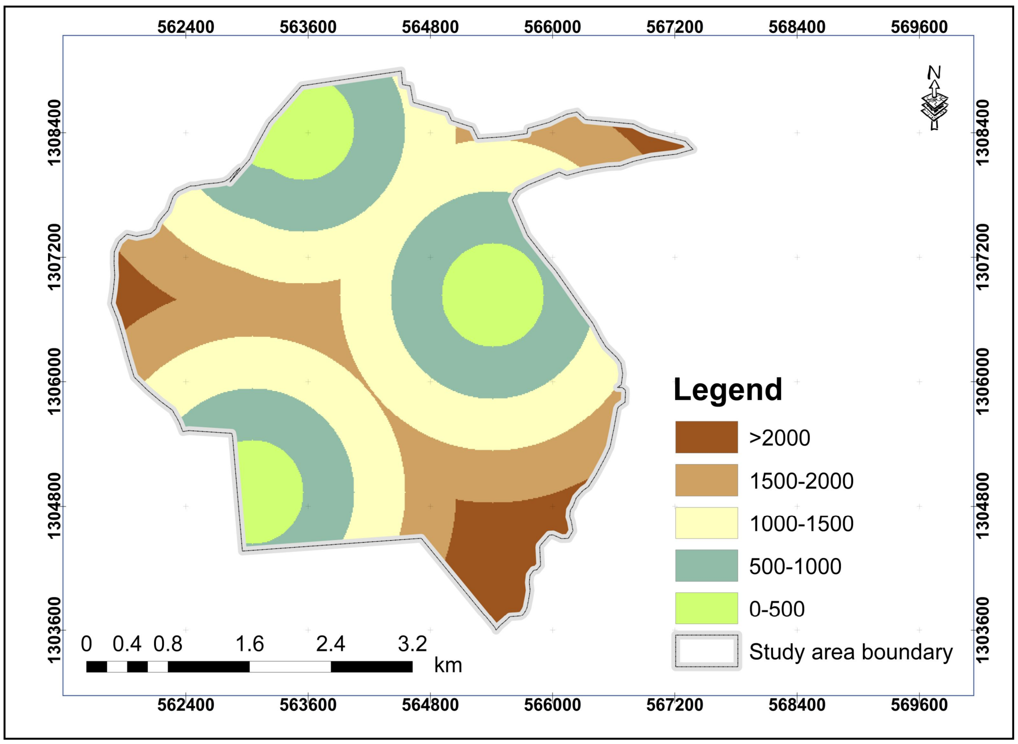


Figure 3.30 Reclassified market centres (meter)

Distance to Transport Centers (distance to bus station)

It is too often that land near public infrastructure (such as a bus station and major road intersection) remains with higher value because transportation investments often increase nearby land values. Empirical studies point out that, the benefits gained by individuals due to transportation improvements includes reduction in commuting cost and time and enhancement in work productivity.

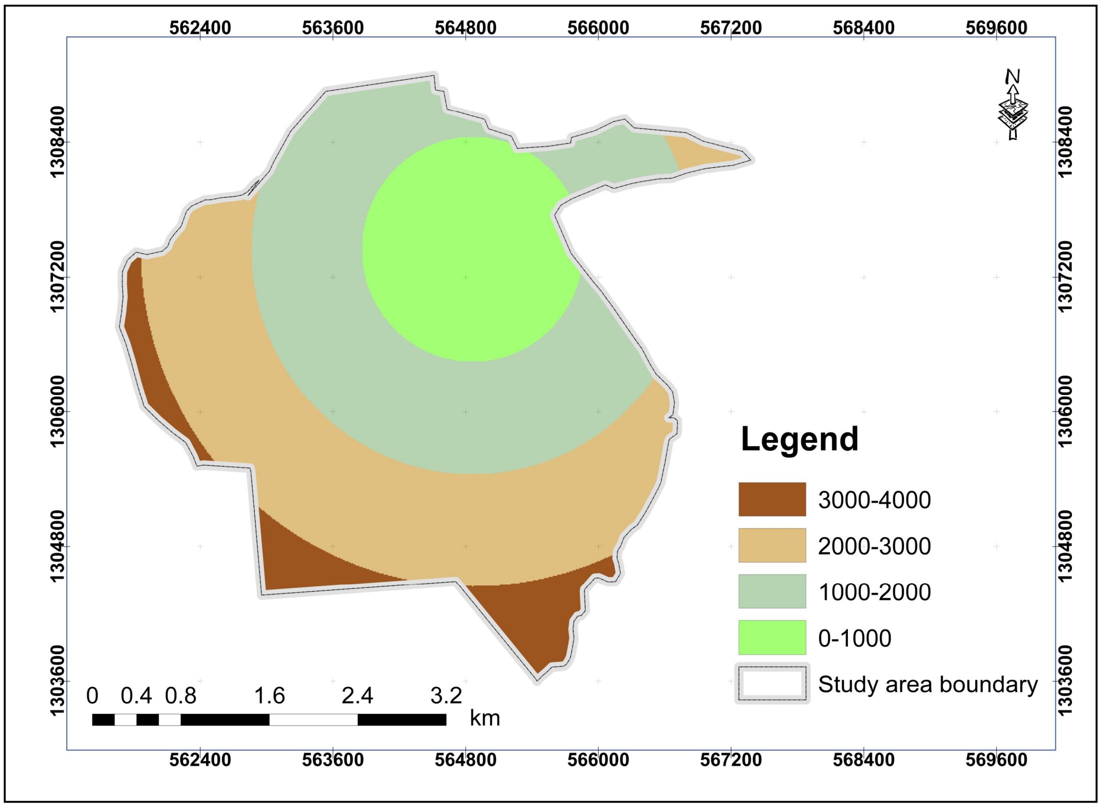


Figure 3.31 Reclassified bus station (meter)

Table 3.19 Summery reclassification of bus station criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Distance bus station	<4000	3000-4000	2000-3000	1000-2000	0-1000

Distance from Visual and Environmental Quality Factors (distance to water body)

Usually, allocating urban land on river banks is pollution caused by open dumping. Hence, this needs to be considered in determining the value of urban land. Thus, the weight given to this attribute and the consequent grades are stated to reflect this situation.

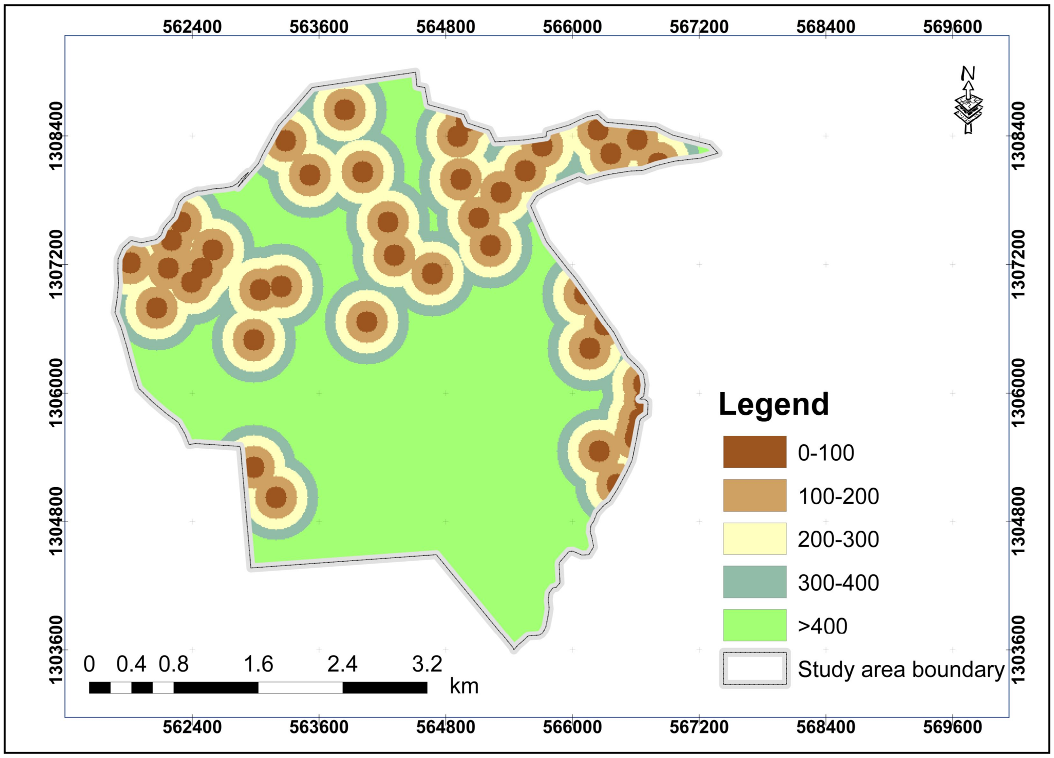


Figure 3.32 Reclassified stream

Table 3.20 Summery reclassification of stream criteria

Type of facility	Most valuable	Very valuable	valuable	Less valuable	Least valuable
Distance to stream	>400	300-400	200-300	100-200	0-100

Housing and Population Density

Housing Density

Urban density is a term used in urban planning and urban design to refer to the number of people inhabiting a given urbanized area per given building. Urban density is considered an important factor in understanding how cities function. It is believed that as the number of building increased the built area will increase and the neighborhood becomes denser. From ground reality, it is known that most municipal service delivery is related to the population density.

In principle, the more the people we have the more service is required. Based on the service provided, the neighborhood quality will be changed as a result the land grade will be improved. As it can be shown in figure 3.33, at the centre of the town is denser than the peripheral this is due to large number of building and at expansion area there is less number of building because they only occupied large number of parcel which is typical manifestation of horizontal expansion.

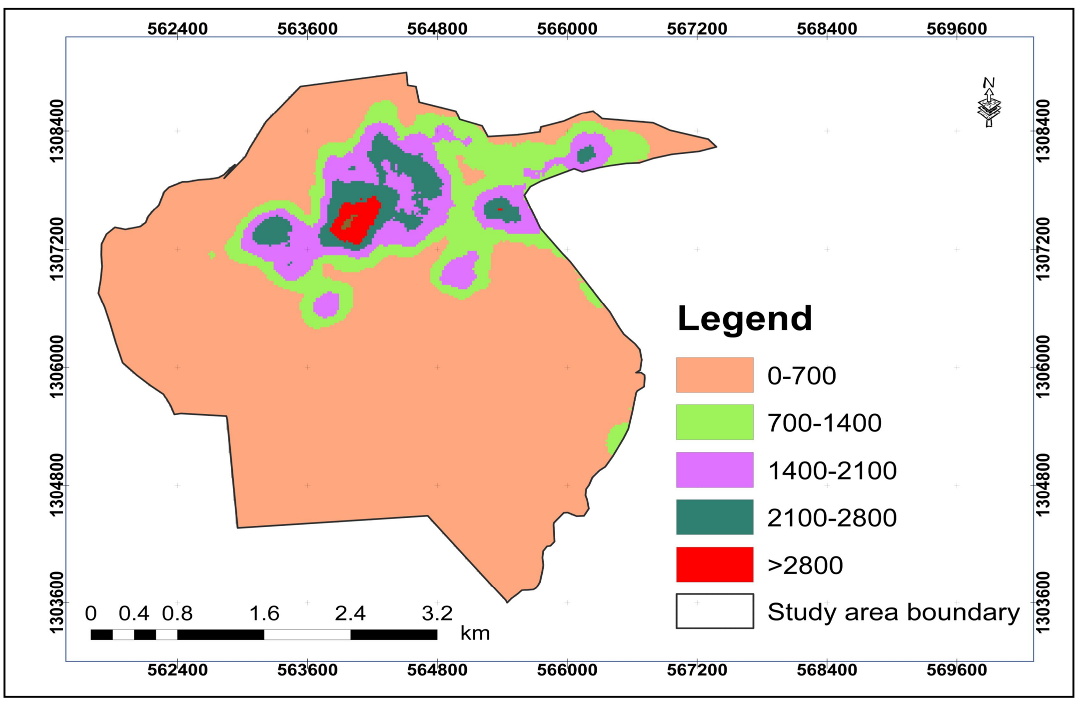


Figure 3.33 Reclassified building density(meter)

3.8 Software Package Used

Software package used for this study includes:

IDRISI Andes used for aggregation of factors by the help of WLC (as fuzzy operator)

ERDAS Imagine 9.2 has been used for image analysis and image interpretation

Arc Map has been used to visual exploration and map preparation

CHAPTER FOUR

4 RESULTS

4.1 Influential Factors and Criteria for Urban Land Grading

4.1.1 Selected Factors for Designing Urban Land Grading

Based on the study under taken the influential factors for designing urban land grading can be coined to the following four pillars.

The first and most important factor in grading a piece of land is its location which is related to accessibility parameter. The finding of this research indicated that the intensive capital investment in the CBD that explain the concentration of the most valuable land in the CBD is gained due to its location advantage which is accessible to transport and infrastructure provision.

The second important factor is related to the surroundings i.e things that border on a piece of land can have a major effect on its value in both positive and negative ways. A building lot on improved neighborhood will probably have a high land grade. Conversely, a plot of land near to land fill or pollutant industrial area will be less desirable for residency. The third factor goes to the state of existing structures. Physical infrastructure development in the form of different structures has a direct impact on urban land grading and therefore on the bench mark price of land.

The fourth factor is related to condition of the land which will have also an effect on its value. For example planned area will be worth more than unplanned area. The geological, environmental condition and psychological perception of the condition of the land has also impact on the land grade and hence on the bench mark price.

Another important finding of this study is that the influential factors for designing urban land grading their roots originated from family of infrastructure and land use provision. In this study, five major factors were identified which fall into five main categories that includes infrastructure, land use, topographic factors and physical conditions, visual and environmental quality and population density.

The study confirmed that among the identified factors infrastructure takes the major's share that has 51% weighting influence and land use is in second position with weight influence 25.6 %. Topography, environmental and visual quality and population density has weight influence of 12.6%, 6.9% and 3.9 % respectively.

4.1.2 Selected Criteria for Each Influential Factor

Evidently, urban land grading is influenced by a large number of criteria. Based on the affirmed fact, in this study twenty four criteria were used for designing the land grade of Woldiya town (Table 4.2). In determining or measuring the value given to each criteria and in establishing the level of desirability of each attribute different measurements and ranges have been used; where most applicable to existing national norms and standards. However, in the absence of known standards expert judgment approach was used.

4.1.2.1 Influence of Urban Spatial Structure on Land Grading

Collectively, the analysis result and literature review makes sure that the urban land structure of Woldiya is composite where by the commercial activities appear clustered near the town center followed by manufacturing and residential uses. The analysis result also revealed that expansion of road simulates the growth of the transportation network by generating centers and sub centers adjacent to roads (Adago, Gonderber and Pizza). This type of growth promotes land value because of increased accessibility along the transportation network. The literature and analysis result strongly confirmed that the manner in which a town grows has significant influence on land use patterns. So, is on land grading.

4.1.2.2 Influence of Urban Land Use on Land Grading

The field work vividly noticed that larger commercial land use types are associated with significantly higher property values which suggest that commercial areas belong to the most valuable in designing urban land grading. In the town, the mixed use of urban land use has also becomes a prerequisite for the commercial development of town.

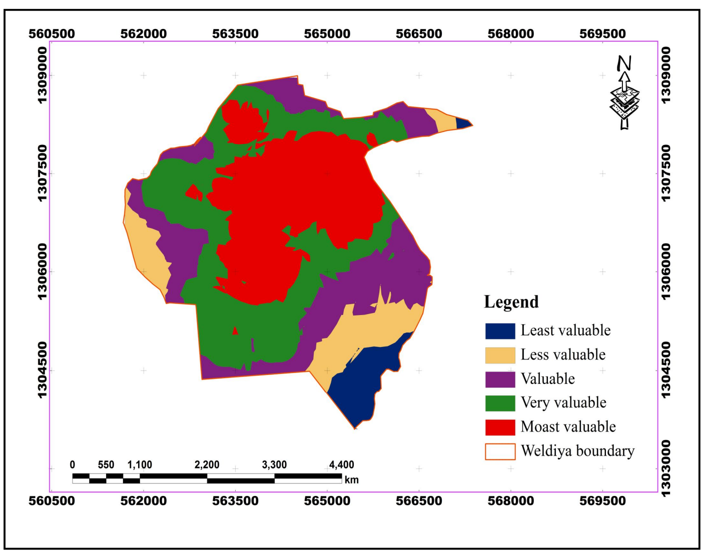
4.1.2.3 Influence of Slope/ Topography on Land Grading

The result of this study has revealed that topographic factor (slope) has impact on the land grading. Table 4.1 and figure 4.1 demonstrates the influence of slope in land grading.

Table 4.1 Influence of slope on land grading

Land grade with slope factor			Land grade without slope factor		
Grade	Area (ha)	Area (%)	Grade	Area (ha)	Area (%)
Least Valuable	206.2	12	Least Valuable	88.3	5
Less Valuable	382	22	Less Valuable	176	10
Valuable	371.2	22	Valuable	386.8	22
Very Valuable	417.5	24	Very Valuable	545.9	32
Most Valuable	345.5	20	Most Valuable	527.5	31
	1722.4	100		1722.4	

As it is indicated on the Table 4.1, when slope is added as one factor, the most valuable area is decreased by 11% in the other hand, the least valuable area is increased by 7%. Furthermore, as it indicated in Figure 4.1 and Figure 4.2 the spatial distribution of the land grading valuation scales has dramatically changed due to the influence of the slope.



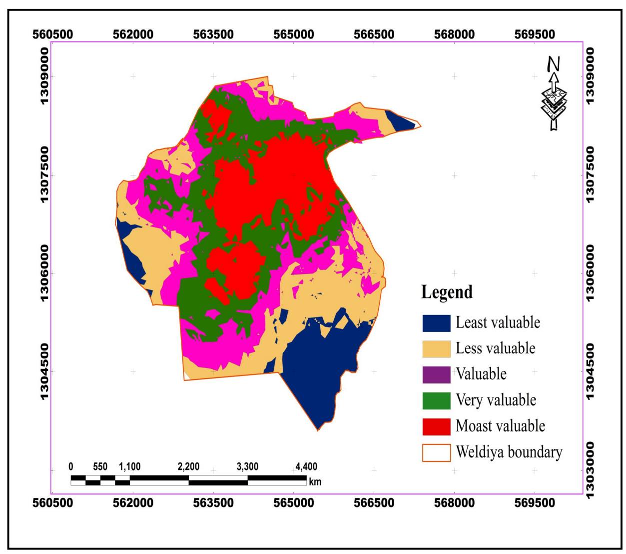


Figure 4.1 Land grade without slope factor

Figure 4.2 Land grade with slope factor

Table 4.2 Selected criteria for the fuzzy land grade

Criteria	Sub criteria	Ranges	Rank	Valuation	Weight
Social infrastructure					
Health facility	Distance to hospital	0-1500	5	Most Valuable	0.0382
		1500-3000	4	Very Valuable	
		3000-4500	3	Valuable	
		4500-6000	2	Less Valuable	
		>6000	1	Least Valuable	
	Distance to health center	0-500	5	Most Valuable	0.0307
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	
Education facility	Distance to University	0-1500	5	Most Valuable	0.0357
		1500-3000	4	Very Valuable	
		3000-4500	3	Valuable	
		4500-6000	2	Less Valuable	
		>4000	1	Least Valuable	
	Distance to high school	0-1250	5	Most Valuable	0.0305
		1250-2500	4	Very Valuable	
		2500-3750	3	Valuable	
		3750-5000	2	Less Valuable	
		>5000	1	Least Valuable	
	Distance to primary school	0-1000	5	Most Valuable	0.02551
		1000-2000	4	Very Valuable	
		2000-3000	3	Valuable	
		3000-4000	2	Less Valuable	
		>4000	1	Least Valuable	
Entertainment	Distance to recreation center	0- 500	5	Most Valuable	0.0204
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	
	Distance to sport center	< 500	5	Most Valuable	0.0179
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	

Accessibility to security	Distance to police station	< 500	5	Most Valuable	0.0150
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	
	Distance to local administration	0- 500	5	Most Valuable	0.0129
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	
Access to public service	Distance to sector office	0- 1000	5	Most Valuable	0.0153
		1000-2000	4	Very Valuable	
		2000-3000	3	Valuable	
		3000-4000	2	Less Valuable	
		>4000	1	Least Valuable	
	Distance to postal service	0- 500	5	Most Valuable	0.0127
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	

Criteria	Sub criteria	Ranges	Rank	valuation	Weight
physical Infrastructure					
Road network	Distance to main roads	0- 500	5	Most Valuable	0.064
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	
	Distance to secondary roads	0-250	5	Most Valuable	0.0384
		250-500	4	Very Valuable	
		500-750	3	Valuable	
		750-1000	2	Less Valuable	
		>1000	1	Least Valuable	
	Distance to collectors	0-100	5	Most Valuable	0.02551
		100-200	4	Very Valuable	
		200- 300	3	Valuable	
		300-4000	2	Less Valuable	
		>4000	1	Least Valuable	
Transportation	Distance to bus station	0-1000	5	Most Valuable	0.0382
		100-2000	4	Very Valuable	
		200-3000	3	Valuable	
		3000-4000	2	Less Valuable	
		>4000	1	Least Valuable	
	Distance to CBD	< 500	5	Most Valuable	0.0890
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	
Market facility	Distance to market center	< 500	5	Most Valuable	0.0639
		500-1000	4	Very Valuable	
		1000-1500	3	Valuable	
		1500-2000	2	Less Valuable	
		>2000	1	Least Valuable	
	Distance to commercial colliders	0-150	5	Most Valuable	0.0890
		150-300	4	Very Valuable	
		300-450	3	Valuable	
		450-600	2	Less Valuable	
		>600	1	Least Valuable	
Land use		Commerce	5	Most Valuable	0.25571
		Mixed	4	Very Valuable	
		manufacturing	3	Valuable	
		Residential	2	Less Valuable	
		Others	1	Least Valuable	

Population and housing density		>20000	5	Most Valuable	0.039066
		15000-20000	4	Very Valuable	
		10000-15000	3	Valuable	
		5000-10000	2	Less Valuable	
		< 5000	1	Least Valuable	
Distance from visual and environmental quality	Flood Line distance or stream line	< 500	5	Most Valuable	
		< 400	4	Very Valuable	0.068938
		300 – 400	3	Valuable	
		200 – 300	2	Less Valuable	
		100 – 200	1	Least Valuable	
Topography	Slope	0-5	5	Most Valuable	
		5-10	4	Very Valuable	
		10-15	3	Valuable	0.0945
		15-20	2	Less Valuable	
		>20	1	Least Valuable	
		North	5	Most Valuable	
	Aspect	East	4	Very Valuable	0.0315
		South	3	Valuable	
		West	2	Less Valuable	
		Flat	1	Least Valuable	

4.2 Results from the Developed Fuzzy Land Grading Conceptual Model

4.2.1 Proposed Framework to develop Fuzzy Land Grading

This paper presents a multi-factor decision making framework for designing conceptual land grading model for urban land valuation mechanisms under a fuzzy environment. The developed conceptual model comprises four steps. Step one discusses about identification phase which includes perception of problem, identification of influential factors and description and pre-processing of alternatives criteria. Step two presents the integrating Geographical Information Systems, fuzzy logic and analytical hierarchy for calculating the final weights of each input layer by using FAHP. Step three deals about aggregation phase, once the criteria maps had been developed and the associated weights assigned to each input layer aggregation stage was undertaken to combine the information from the various factors. Step four presents about the evaluation phase that deals how well does the conceptual model agree with actual ground reality based on the results obtained.

4.2.2 Fuzzy Analytical Hierarchy Process (FAHP)

This study used the FAHP to determine the criteria weights from judgments of decision-making domain experts. The research utilized the Fuzzy Extent Analysis (FEA) method to calculate the fuzzy consistency ratio (FCR) and the result was obtained 0.06.

4.2.3 Integration of GIS and FAHP

The system integrates two major tools (GIS and FAHP) in a manner that can assist the study in determining appropriate fuzzy land grading system. The system was successfully able to generate the land grade model of the study area. The following section presents the major findings of the fuzzy conceptual model (Fig 4.3).

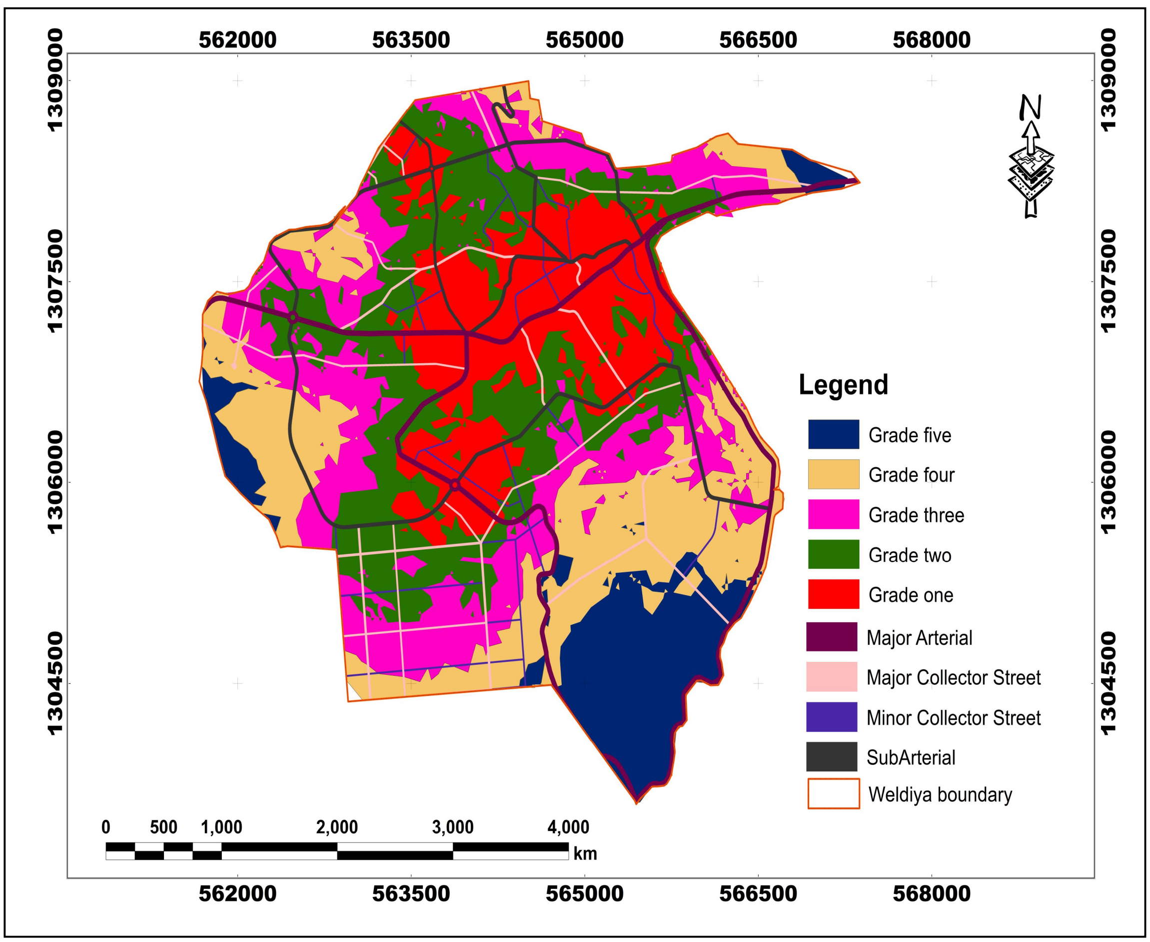


Figure 4.3 The developed fuzzy land grade map

- As it is indicated in Figure 4.3, the main reasons for which most valuable areas (red color) are placed in the inner town is because of its proximity to existing CBD in which the probability of finding existing infrastructure and organized service system is high, its proximity to recreational sites, shopping centers and commercial areas that represent a first necessity for any economic activity, its proximity to main roads and its good connection to the market and access to transportation nodes are the most important factors.
- The advantageous location and intensive capital investment in the CBD may explain the concentration of the most valuable land around the center of the town.
- The general pattern of urban land value tends to decrease from the urban center to the periphery with some exception.
- Instead of showing a monotonous concentric pattern like Burgess Model the fuzzy GIS approach follows the composite of the sector and concentric land use models.
- The result also demonstrated that physical infrastructure development has a direct impact on urban land grading. In the other hand, the steep slopes, wetlands and water areas also limit the gradual transition of the urban land values of the land grading.

4.3 Suitability of Fuzzy Approach for Designing Urban Land Grading (Comparison of Crisp and Fuzzy Logic)

In order to be able to illustrate the differences between a fuzzy logic and a crisp approach, two different maps were produced by using the two methods. In figure 4.4 all the factor maps created with the crisp approach are combined by using an OR operator. In Figure 4.5 the fuzzy factor maps are combined with the WLC operator. The results show that the fuzzy approach is more reasonable and reflects the human perception in better way. The crisp boundaries disappear and are replaced by a gradual decrease in land grading as distance away from each feature increases. This situation reflects the way in which a person might possibly perceive land grade. Furthermore, this condition matches with the ground reality. As indicated in Figure 4.5 land grade evaluations via fuzzy method increased and improved some land value classes. This indicates that flexibility is another characteristic of fuzzy logic

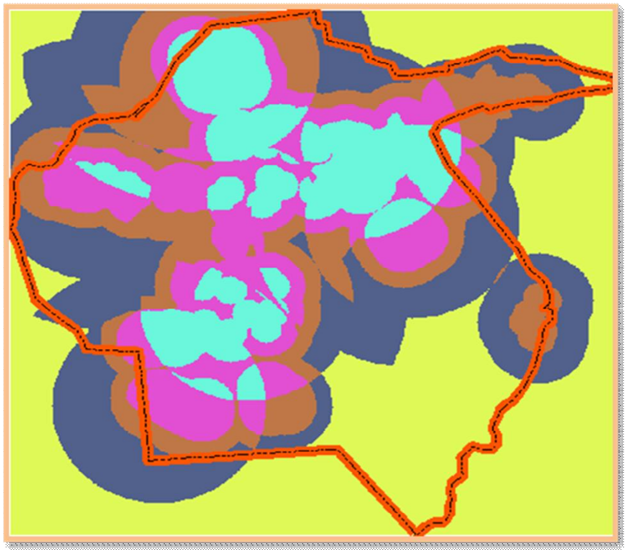


Figure 4.4 Result from Boolean operator

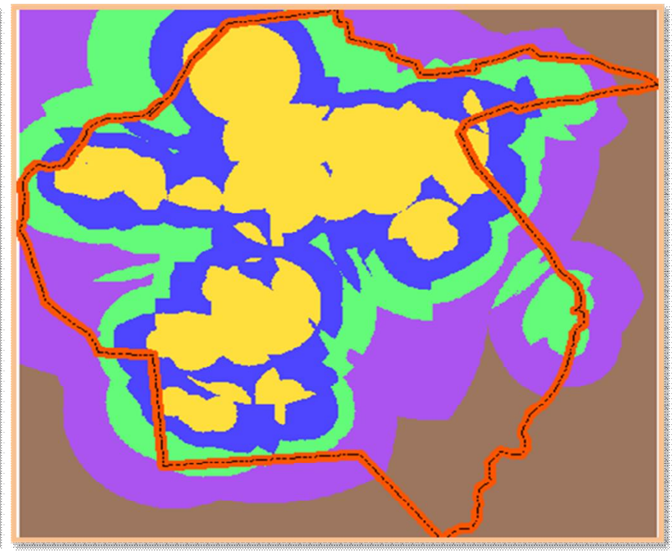


Figure 4.5 Result from fuzzy operator

4.4 Comparison between the Existing Land grading and the Fuzzy Land Grading

The difference can be best illustrated by considering the existing land grade map (Fig.4.6) and Table (4.3) which was prepared before but covers only a small part of the town. This indicates that the preparing and implementing the urban land grade plan in the urban locality have not substantially developed and have not constantly updated based on the time frame. The traditional approach is static and an aesthetic exercise than a dynamic process tied to real market development and land valuation. The traditional approach lacks sufficient flexibility. Furthermore, the important influential factors in land grading like topography is not considered. Yet, the notion of mono centric concept is dominant model. However, the fuzzy land grading provides composite (concentric and sector) model that reasonably represent real land use patterns in the study area.

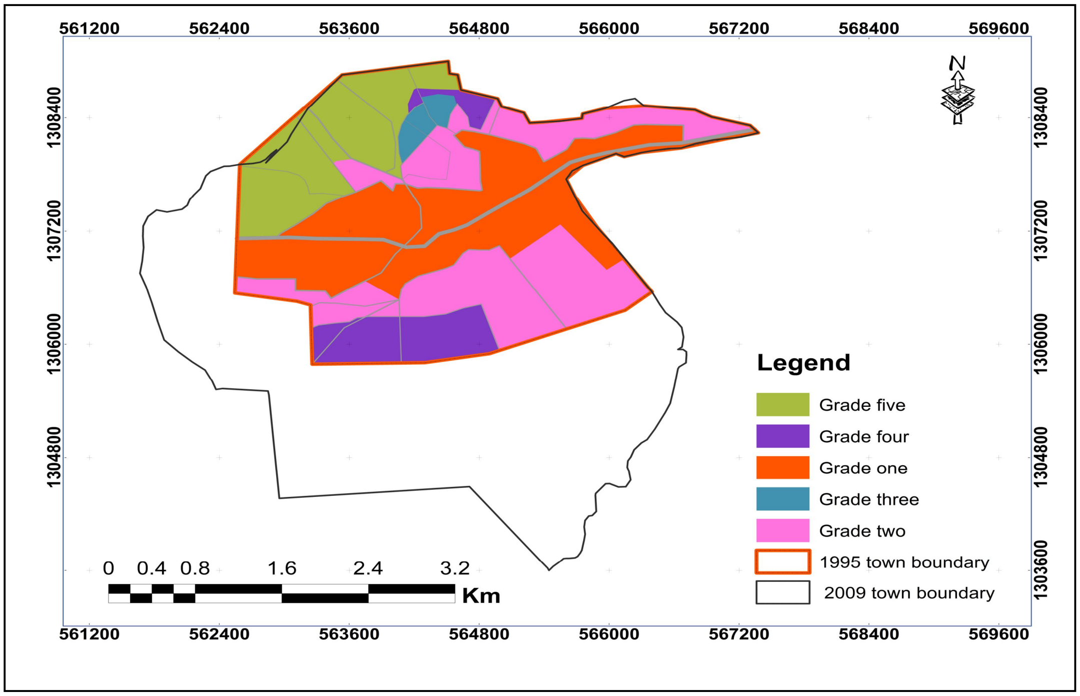


Figure 4.6 Existing land grade map

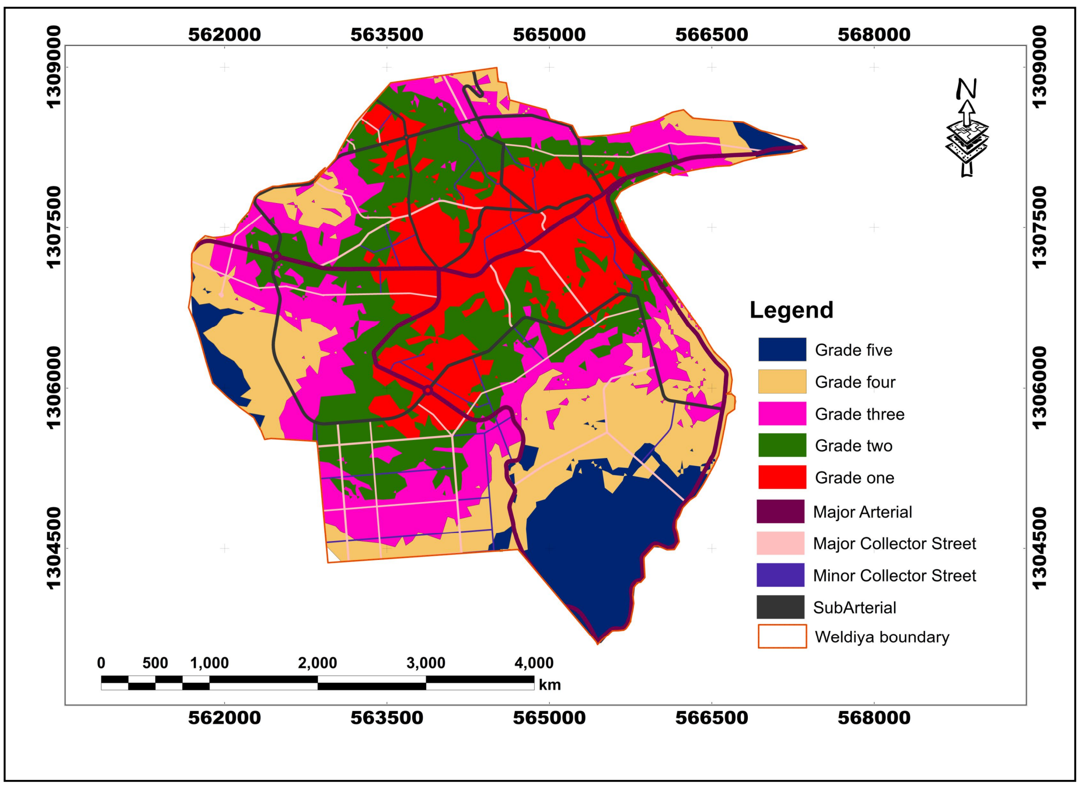


Figure 4.7 Fuzzy land grade map

Table 4.3 Comparisons between existing land grading and fuzzy land grading

Grade	Existing land grade		Fuzzy land grade		Rate change (%)
	Area (ha)	Area (%)	Area (ha)	Area (%)	
Grade one	212	24.43	527.5	31	+5.37
Grade two	159	18.32	545.9	32	+4.28
Grade three	181	20.85	386.8	22	+2.85
Grade four	115	13.25	176	10	-3.25
Grade five	201	23.15	88.3	5	-18.15
Total	868	100	1724	100	

As it can be shown in Table 4.3, grade one, grade two, grade three have positively increased by 5.37%, 4.28% and 2.85% respectively. This result is happened due to infrastructure development and expansion of the town indifferent direction that causes to emerge center and sub centers that could bring vibrant urban centers. Grade four and grade five shows a decline growth this indicated that the least valuable land is converted to valuable land due to the urban dynamics and infrastructure and development of commercial nodes and colliders.

CHAPTER FIVE

5. DISCUSSION

In the context of this study, the development of fuzzy urban land grading is addressed through the investigation of influential factors of urban nature as indicators of urban land quality, which in turn are key determinant for land grade development which includes infrastructure, land use, topography and environment aspects. The analyzed data also confirms that absence of well-defined or in adequately identified factors can hamper the functioning of land grading and leads to inefficient land market. It is important to note that the factors cannot be generalized for all towns and cities since there are considerable variations between different cities in term of size, planning principles, functions and topography, etc. However, the factors can be used as template to develop urban land grade information system.

The analysis result of Saba et al., (2011) reinforced that there is yet no universal agreed upon mechanism of defining evaluation criteria for multi criteria decision making. According to Saba et al., (2011), to be able to accurately define all aspects of the decision problem, there is generally a need for a large number of criteria to be included in the process. Choosing a small number of criteria might result in over simplifications. On the other hand each evaluation criterion must be comprehensive and measurable and the set of criteria should be close to being complete such that it covers nearly all aspects of the problem. The selected criteria should also be relevant to the analysis and also decomposable (broken into parts to simplify the process), non-redundant (avoid double counting) and minimal. Furthermore, the selection process has to be tailored to the needs of the problem at hand and be based on the characteristics of the system that is analyzed.

One gap identified by this research is that the land grade models have concentrated only on the proximity analysis (how far and how close to a given center of facilities). This can manifested by the work of Danel (1992) that he was used 17 criteria without considering topography. In doing so, he failed to consider other potential influencing factors such as slope and aspects that could have influence in determining urban land grade. Especially, a country like Ethiopia which has very undulating topography has profound impact on the land quality as well as on the land valuation. The results in Table 4.1 reflect the perception that missing important criteria like topography can affect the model outcome to a certain degree.

It is important to add that the major factors affecting land grading could be similar in different cities and towns but the level at which they influence land grading is different in different cities and towns. Hence we cannot assume that each evaluation criteria is of equal importance. This difference can be handled by weight calculation which is one of the most important calculations in multiple factor assessment method. One of the useful methods of determining the factor criteria weights is Analytical Hierarchy Process (AHP) introduced by Saaty (1980). However, within the literatures it is underlined that the conventional AHP technique of expressing decision maker‘s judgments in the form of single numbers does not fully reflect a style of human thinking in the real-world system.

In order to overcome this incompetence, this research uses the FAHP to determine the criteria weights from judgments of decision-making domain experts. In similar way researchers Ibrahim *et al.*, (2011) and Rodney *et al.*, (2011) use FAHP and they reported that the FAHP approach allows decision makers to give interval judgments which can capture a human‘s appraisal of ambiguity when complex multi-attribute decision making problems are considered. Furthermore, researchers like Ibrahim *et al.*(2011) have discussed that the preference ratio should be about 10%, or less for the weights to be acceptable otherwise the decision maker may need to reexamine the judgment process of assigning the weights. In this study the preference ratio values also known as FCR was calculated (equation 3.7) and the obtained result is lower than 10% i.e 0.0600 which FCR is less than 0.10 that indicates a reasonable level of consistency.

The analysis result and review shows that fuzzy logic is one of the new alternative approaches to spatial modeling that has emerged originally and formulated by Zadeh (1965), fuzzy logic replaces the crisp and arbitrary boundaries with a continuum, thereby allowing the uncertainty associated with human perception and individual concept definition to be captured. In the last few years, numerous attempts to handle this uncertainty and imprecision have been carried out by means of fuzzy set theory and the applications of fuzzy set theory to multi-criteria evaluation methods. Under this framework several researchers have proven that the method of integrating fuzzy logic and GIS and determining the weight of the factors by using fuzzy analytical hierarchy process (FAHP) is effective method to study geographical phenomena that have fuzzy characteristics (Hong and Roland, 2000, Khalil, 2008, Ibrahim *et al.*, 2011, Peter *et al.*, 2011, Rodney *et al.*, 2011 and Jayasree *et al.*, 2013).

Factors that influence land grade have been documented in different literatures (MUDW, 2006, Recep *et al.*, 2006 and Mehmet and Ayse, 2009). As it is indicated in the methodology part (Fig.3.7) multiple factors assessment method has been used in designing the urban land grading. And this paper uses it as a primary method to develop the fuzzy land grading model. The method generally takes account of as many characteristics of urban land, urban infrastructure, topographic and environment factors. The method proposed here considers information in a similar way to (Daniel, 1992 and Liu, 2002). This research considers the identification of well-defined influential factors is a fundamental tenet in designing urban land grading. In like manner, the absence of adequately identified factors can hamper the functioning of land grading and leads to inefficient land market. The theoretical background of this approach is also similar to the concept of Saba *et al.* (2011).

The conceptual model of this study comprises four steps. Step one discusses about identification phase which includes perception of problem, identification of influential factors and description, application and pre-processing of alternatives criteria. Step two presents the integrating Geographical Information Systems, fuzzy logic and analytical hierarchy for calculating the final weights of each input layer by using FAHP. Step three deals about aggregation phase, once the criteria maps had been developed and the associated weights assigned to each input layer aggregation stage was undertaken to combine the information from the various factors. Vladimir and Dmitry (2004) also adopted similar methodological frame work. Furthermore, WLC was chosen as the method of aggregation at this stage of the research because WLC is utilized as fuzzy operator. In similar way Hong and Ronald (2000) in their finding indicated that WLC can be used as fuzzy operator.

As it is presented in section 4.3 the results show that the fuzzy approach is more reasonable and reflects the perceived impact of manmade features much better than the crisp. The crisp boundaries disappear and are replaced by a gradual decrease in land grading as distance away from each feature increases. This situation reflects the way in which a person might possibly perceive land grade. Hence, this indicated that flexibility is another characteristic of fuzzy logic. Furthermore, this condition matches with the ground reality. Study by Rodney (2011) also confirmed that the fuzzy approach allowed judgments to be made as a set of intervals in order to capture a human‘s appraisal of ambiguity. In similar way Ibrahim *et al.,* (2011) was able to notice the fuzzy modeling show better flexibility than the crisp.

A comparison between results of this research and other investigators as well as (Daniel,1992) indicates that the main reasons for which most valuable areas are placed in the inner town is because of its proximity to existing CBD in which the probability of finding existing infrastructure and organized service system is high, its proximity to recreational sites, shopping centers and commercial areas that represent a first necessity for any economic activity, its proximity to main roads and its good connection to the market and access to transportation nodes are thus the most important factors.

The analysis result of this study confirms that larger commercial land use types are associated with significantly higher property values which suggest that commercial areas belong to the most valuable in land grading. Similarly, mixed land use types may lead to increase to land values. The study also demonstrates the impact of land use categories on bench mark price. For example, in Addis Ababa case, land rent for residential activities the rent ranges from a maximum of 2.38 birr /m^2 to a minimum of 0.09 birr/m^2 and rental rates and lease price for commercial are ranges from a maximum of 4 birr /m^2 to a minimum of 0.8 birr/m^2 while land uses rental rates and lease price for industrial ranges from a maximum of 2 birr /m^2 to a minimum of 0.4 birr/m^2.This shows that commercial area is most valuable while industrial area is very valuable as compare to residential area.

The analysis result revealed that instead of showing a monotonous concentric pattern like Burgess Model the fuzzy GIS approach follows in manner of gradual transition. i.e the land grade is mix of the sector and concentric land use models which deviates from the traditional land use models (section 2.1). The conceptual model supports composite urban structure where by the commercial activities appear clustered near the town center, followed by transport route and residential uses. For example land values around nodes, intersection poles and commercial colliders can increase land value. In fact, the result of this study indicated that the general pattern of urban land value tends to decrease from the urban center to the periphery and the most valuable land is situated in the old section of the town where comprehensive infrastructure has been developed during the long history of growth. This finding is also resembles to the model of Bid Rent theory.

To sum up, the fuzzy GIS approach gives more flexible urban land grading in Woldiya than the Boolean logic-based traditional approach. Furthermore, urban land use exhibits many patterns that reshape the urban spatial structure which cause different change in land grading. Thus the study reveals that there is strong relationship between urban spatial structure and land grading. The traditional grading approach, which emanating from the model of a mono-centric city cannot accommodate the rapid urban land use change.

CHAPTER SIX

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The finding of this study assured that the influential factors for designing urban land grading in Woldiya town can be coined to four pillars. The first and most important factor in grading a piece of land is its location which is related to accessibility parameter. The second important factor is related to the surroundings i.e things that border on a piece of land can have a major effect on its value in both positive and negative ways. The third factor goes to the state of existing infrastructure development. The fourth factor is related to condition of the land which will have also an effect on its value. Another important finding of this study is that the influential factors for designing urban land grading their roots originated from family of infrastructure and land use provision.

GIS Fuzzy Conceptual Modeling (GISCFM) is a new approach based on fuzzy logic integration with GIS. It is an appropriate methodology to support location choice and land grading assessment. In any of these methods, factor identification, weighting and integrating GIS and fuzzy logic approaches are important prerequisites that serve as platform to develop land grading. In all, land can be classified for the anticipated grades based on the trend of uses and physical and socio economic and environmental factors. This paper indicates the fuzzy modeling approach can avoid the loss of information that often arises when the strict Boolean logic is used on the basis of the crisp sets (Yes/No).

To sum, the fuzzy land grading method can produced a better and more reasonable result than using pure Boolean operators. It is, however, important to notice that the fuzzy system does not mean that there are not disadvantages. The main of them is the lack of ready to use membership functions and traditional techniques have existed for a long period and are widely accepted it may take time to introduce the fuzzy system.

6.2 Recommendations

Achieving efficient land use, encouraging investors and investment and realizing the cost of urban land and make an efficient use of it are some of the major national and regional goals in Ethiopia. Furthermore, planning and managing cities in the new era of globalization is becoming demanding task calling for new skills and approaches. Among these issues having efficient land grading takes the major's share. To take advantage of the efficient land grading the following recommendations should be paid due attention.

Facilitate Training to Local Staffs

Training of the local government staffs, particularly those sections which have direct relation to land management should be the first priority. The plan preparation, implementation and monitory of any urban plan need technical staff to follow its impact on the urban development. This is a difficult task unless there is sufficient qualified manpower that can assess and updated information.

Allow Participation

One of the major problems to be addressed for the successful implementation of the urban policy in the country as a whole is the lack of awareness and understanding of the contribution from stake holder participation. Likewise, the preparation of land grade requires adequate participation by the relevant stakeholders during the preparation and implementation of different regulations that enables to implement the land grade.The bench mark price of land grades shall be made accessible to the public via different public media.

Develop Proper Cadastral and Land Register System

Develop clear and transparent instructional operations, procedures and legal formalities in the registration and titling of land holding. Without a proper updated cadastral maps and land registry system it is difficult to have a clear picture of the land grading and land valuation system.

Allow Flexible Urban Planning Approach

Plans must have flexibility to provide for ever-growing and ever expanding city boundaries and infrastructure development.

Providing Accurate and Up-to-Date Geospatial Information System

The local urban planning authorities and agencies should adopt new technologies like computerized data base and GIS application. Because these have capability to provide necessary spatial data for preparation of base maps, for planning proposals and act as monitoring tool during implementation phases.

Update the Land Grade as Per the Proposed Time Frame

The land grade has to be constantly updated and it should be updated on the basis of defined time frame. Given the rapid infrastructure development and construction work that is being carried out in the town, the growing need for redevelopment, radical changes in the town's space organization the land grade has to be updated as per the lease proclamation i.e every two year.

Providing Regulatory Framework

There should be an institution or even a department under the land administration authority which is responsible for this particular task. This institution should be responsible for monitoring new developments, updating the land grade, facilitating stakeholder participation in the review process and making the updated land grade public information

To sum up, the study methodology can be used as template to develop urban land grade information system. Furthermore, users may modify the fuzzy land grade model in two ways (a) adding data layers not included in the original model that add value to the analysis and (b) changing weights in the model to better reflect land use planning priorities and perspectives in a particular jurisdiction. In future research, the researcher recommends using different fuzzy mathematical programming method to improve the conceptual model. Also, the researcher recommends applying this model on a WebGIS to receive the basic bench mark price of the land information.

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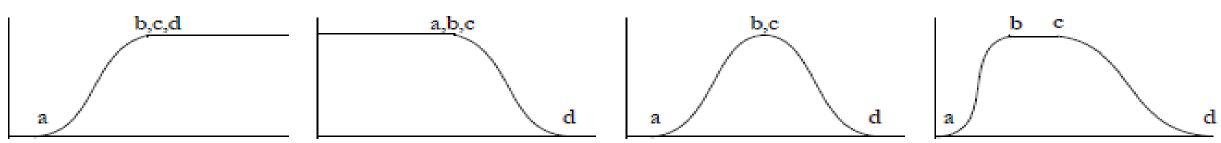
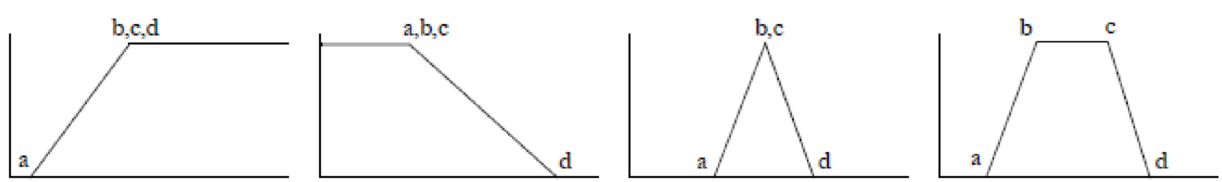
Appendix A

$A_{1.}$ Applying Membership Functions

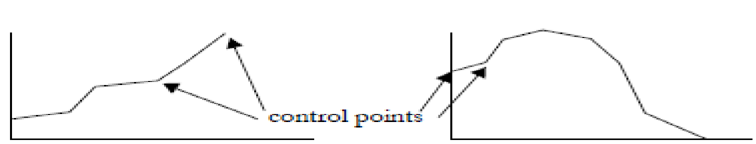
The Fuzzy Membership tool reclassifies or transforms the input data to a 0 to 1 scale based on the possibility of being a member of a specified set. 0 is assigned to those locations that are definitely not a member of the specified set, 1 is assigned to those values that are definitely a member of the specified set, and the entire range of possibilities between 0 and 1 are assigned to some level of possible membership (the larger the number, the greater the possibility).Three are four types of membership functions: (i) linear membership functions, (ii) sinusoidal membership functions, (iii) J-membership functions, (iv) user defined. In this study user define membership is used in order to apply the classified range of measurement.



Sinusoidal membership functions

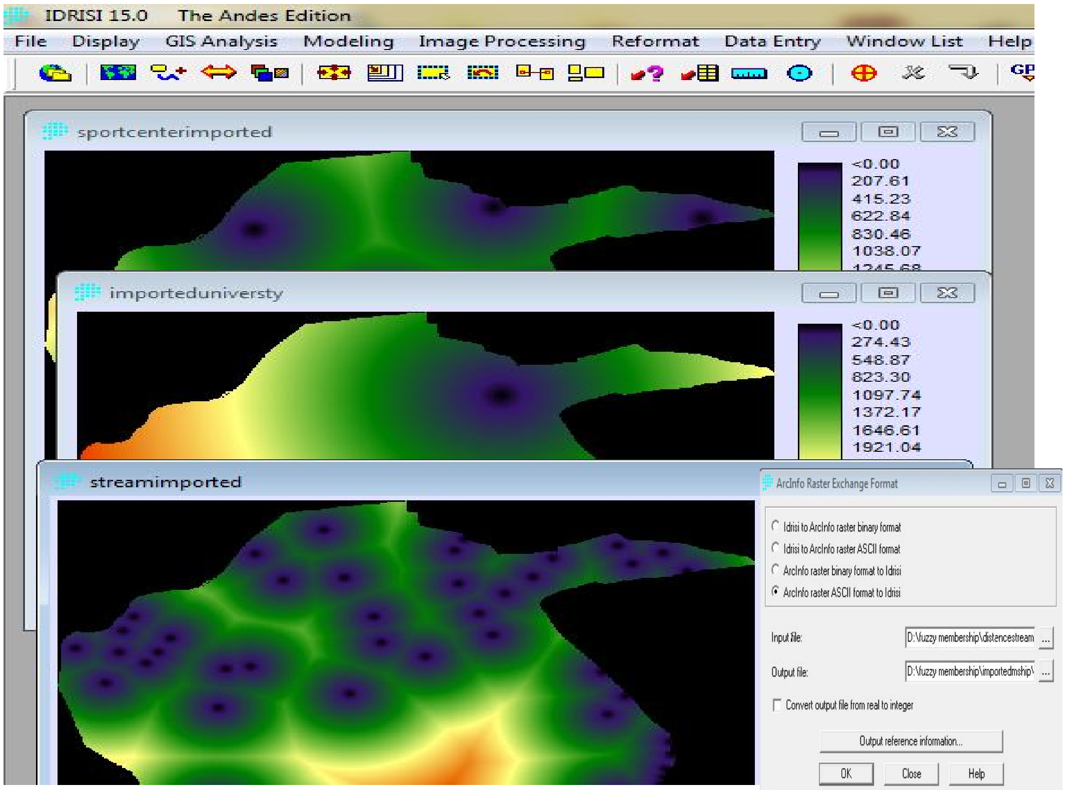


Linear membership functions

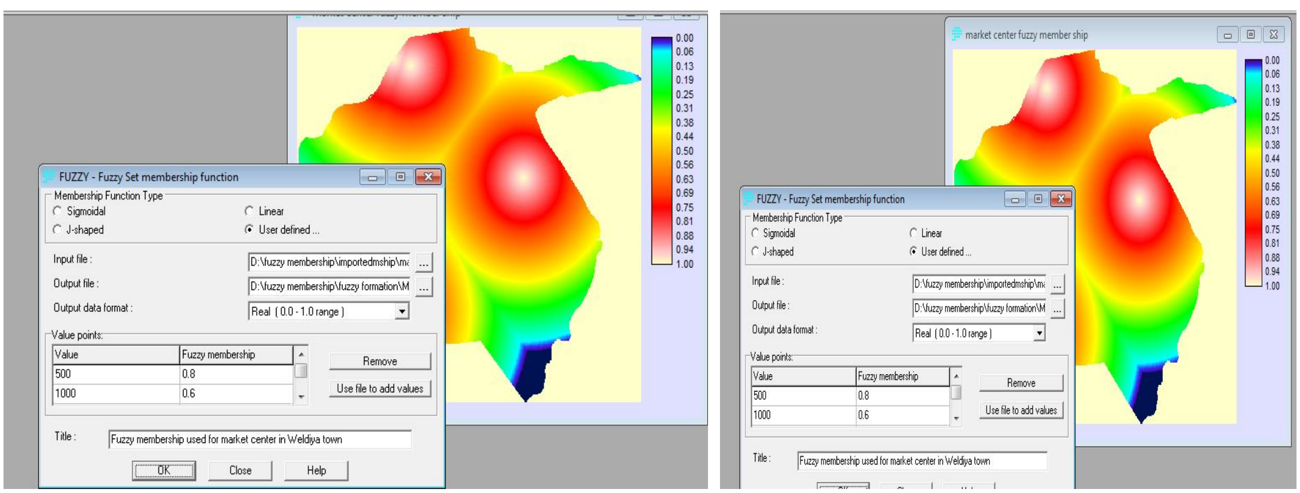


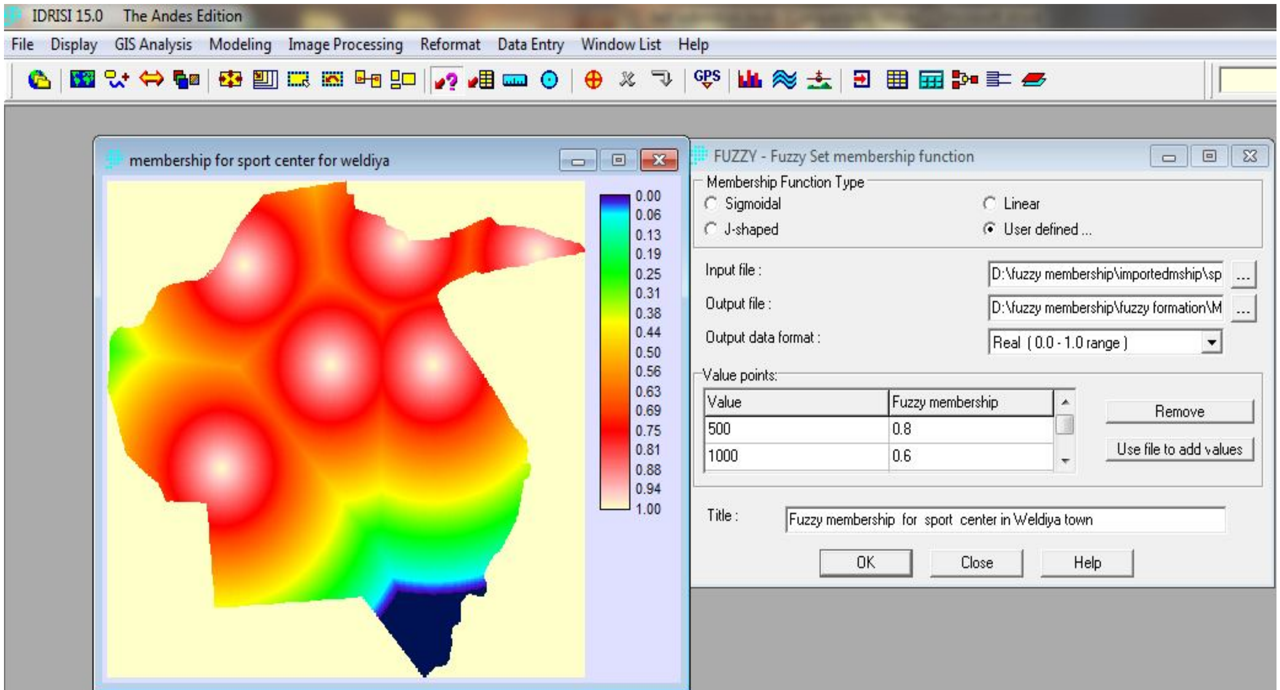
User defined member ship

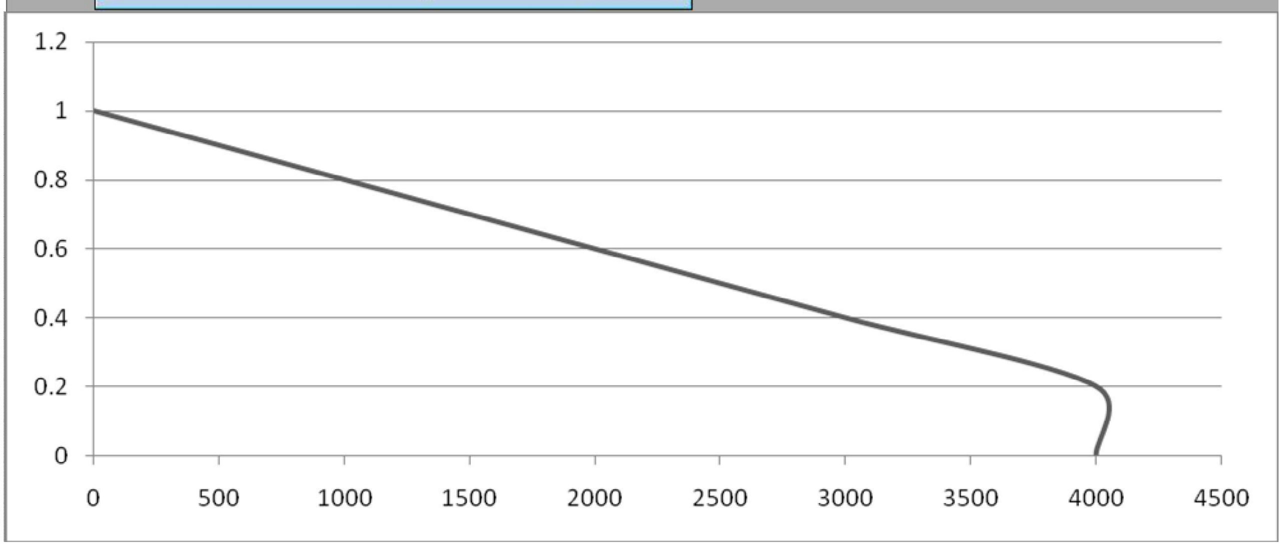
A2 Sample Factor Maps Imported from GIS to IDRISI



A3 Sample Membership Functions of Factors







This graph shows when the distance is less than 500m the member ship belongs to one. This shows that the most valuable part of the land is in the range of 0-500metere

Appendix B

How Fuzzy Integration works

Fuzzy And

The Fuzzy And overlay type will return the minimum value of the sets the cell location belongs to. Fuzzy And uses the following function in the evaluation.

Fuzzy And Value = min (factor1, factor2,..., $factor_{n)}$

Fuzzy Or

The Fuzzy Or overlay type will return the maximum value of the sets the cell location belongs to. Fuzzy Or uses the following function in the evaluation.

Fuzzy OR Value = max (factor1, factor2,..., $factor_{n)}$

Fuzzy Product

The Fuzzy Product overlay type will, for each cell, multiply each of the fuzzy values for all the input criteria. Fuzzy Product uses the following function in the evaluation:

fuzzyProductValue = product(factor1, factor2,..., $factor_{n)}$